

APPENDIX 1. BENCHMARK SCENARIO 1, Experiment 1. t_policy_year = 4000.

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Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

```
In[21]:= RangeData[data_] := data[[1]][[4]][[3]];
```

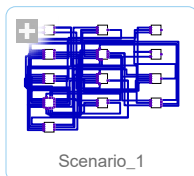
Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

```
In[22]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Here are some high-level properties of unmodified Benchmark Scenario 1.

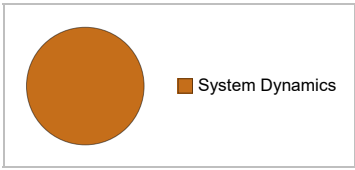
```
In[23]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_1"]
```

Out[23]=



```
In[24]:= mysummary = mysim["Summary"]
```

```
Out[24]=
```

Model	SystemDynamics.WorldDynamics.World3.Scenario_1
Description	Original WORLD3 model
Simulation Interval	True
Policy Year	0
Case Count	106
Base Case	True
Simulation Years	265
Simulation Days	265
Diagram	

Show the default value of `t_policy_year`.

```
In[25]:= SystemModel[mysim][{"ParameterValues", "t_policy_year"}]
```

```
Out[25]=
```

```
{t_policy_year → 4000}
```

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

```
In[26]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[26]=
```

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[27]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[27]=
```

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[28]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[28]=
```

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[29]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[29]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[30]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[30]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[31]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[31]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[32]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[32]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[33]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[33]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[34]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[34]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[35]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[35]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[36]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[36]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[37]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[37]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[38]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[38]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[39]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[39]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute Benchmark Scenario 1 and plot various variables

```
In[40]:= basesim = SystemModelSimulate[mysim]
```

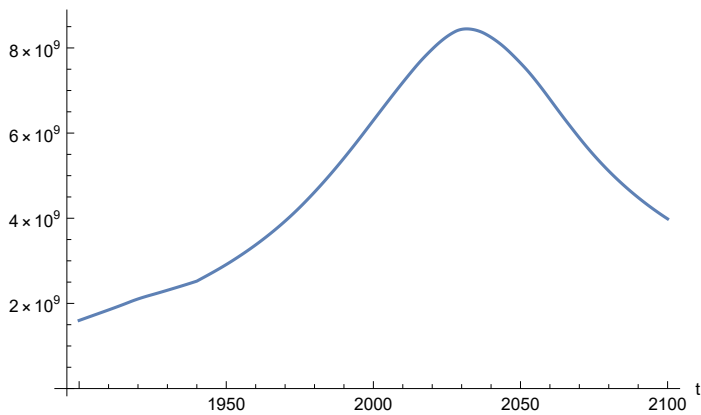
```
Out[40]=
```

```
SystemModelSimulationData [  Model: Scenario_1  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[41]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[41]=
```



Find max and min of population values.

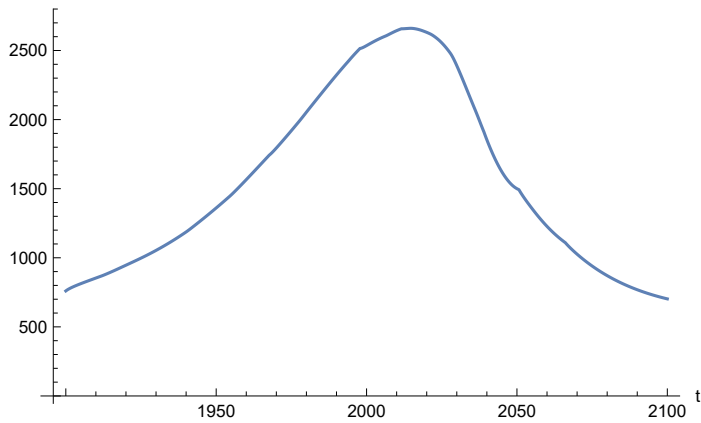
```
In[42]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.4473 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[43]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

Out[43]=



Find max and min of y values.

In[44]:= **MinAndMax**[basesim[{"Food_Production1.Land_Yield.y"}]]

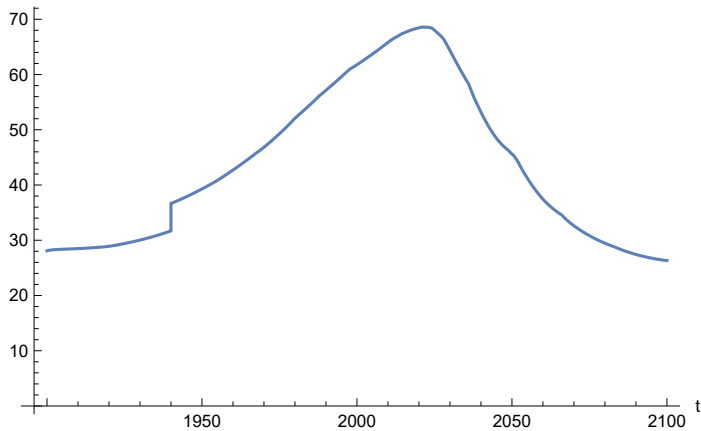
Maximum is 2660.5

Minimum is 702.501

Plot life expectancy, years.

In[45]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

Out[45]=

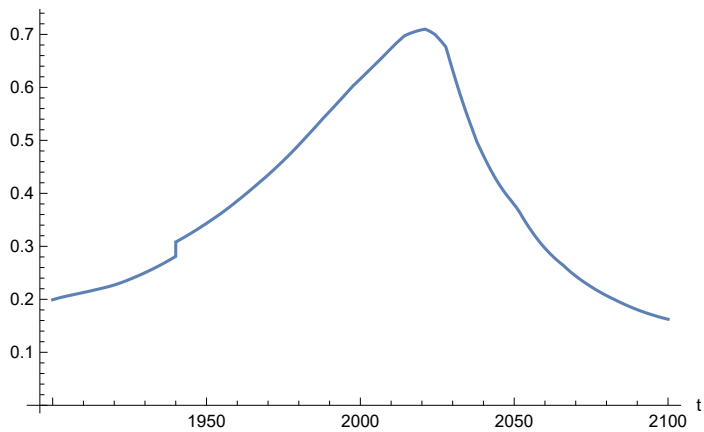


In[46]:=

Plot human welfare index.

```
In[47]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

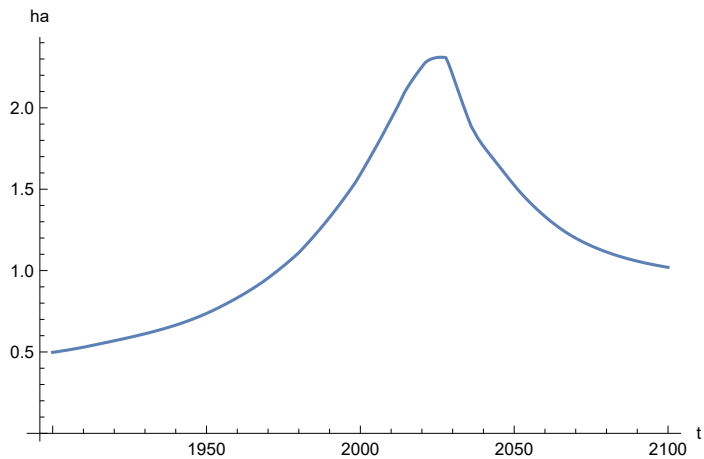
Out[47]=



Plot per capita ecological footprint, hectares.

```
In[48]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```

Out[48]=



Find max and min of y values.

```
In[49]:= MinAndMax[basesim[
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]]
```

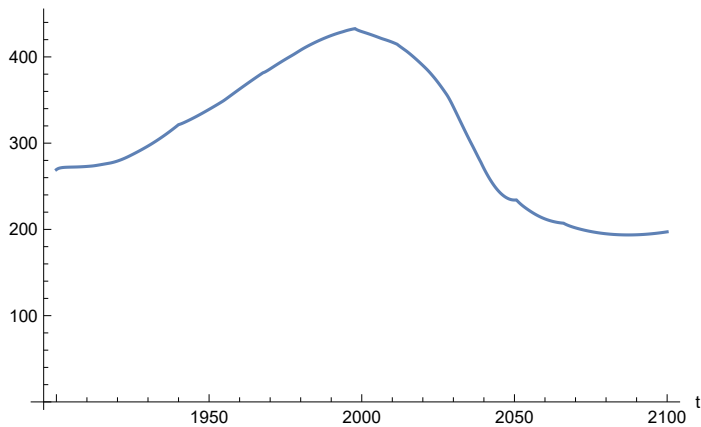
Maximum is 2.31082

Minimum is 0.497387

Plot food production per capita (kg/year).

```
In[50]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[50]=



Find max and min of y values.

```
In[51]:= MinAndMax[basesim[{"Food_Production1.Food_PC.y"}]]
```

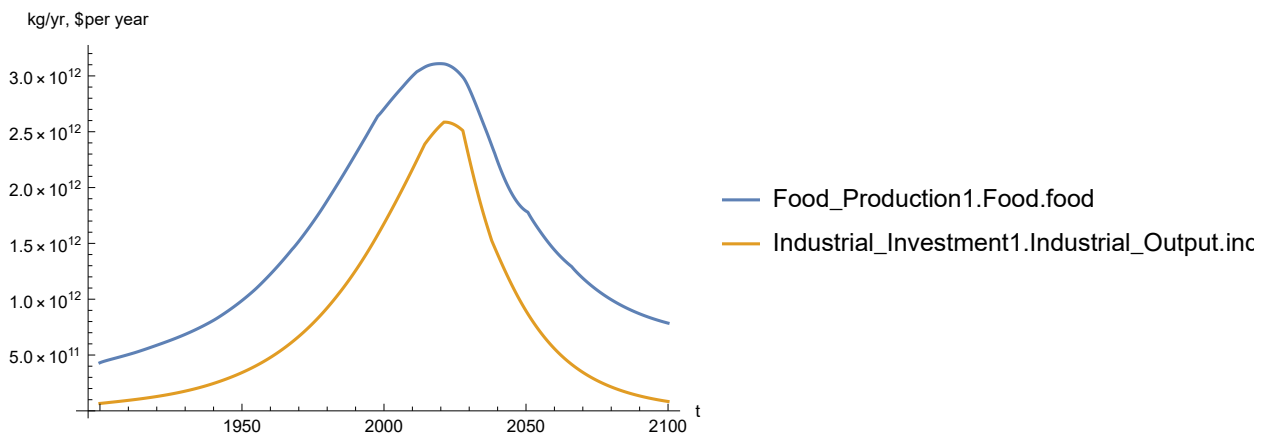
Maximum is 432.786

Minimum is 193.587

Plot total food production (kg/year), and industrial output (dollars/year).

```
In[52]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[52]=



Find max and min of y values.

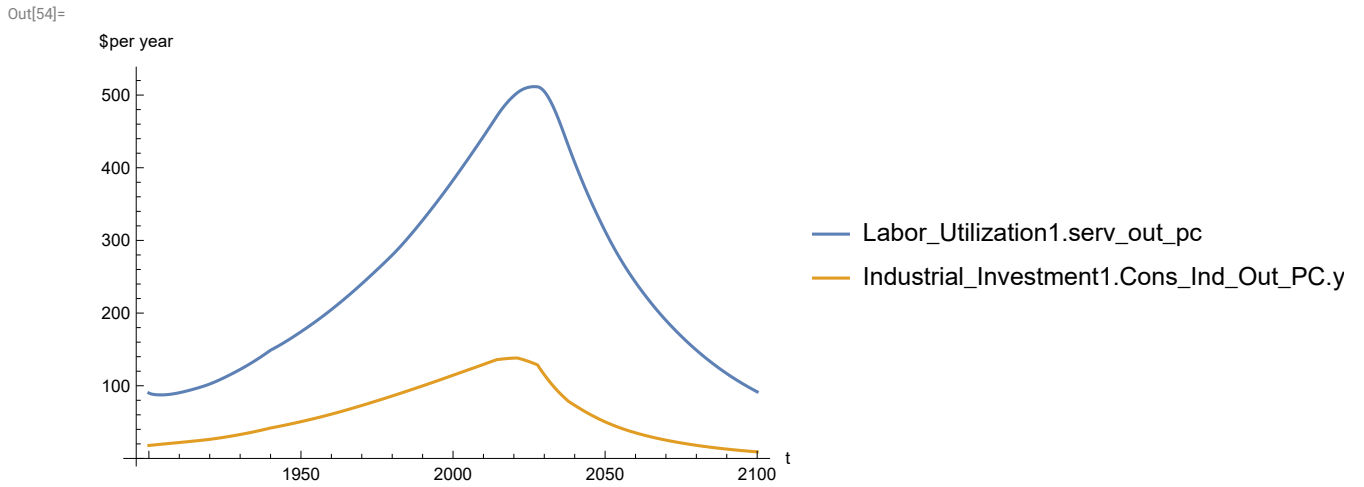
```
In[53]:= MinAndMax[basesim[{"Industrial_Investment1.Industrial_Output.industrial_output"}]]
```

Maximum is 2.58591×10^{12}

Minimum is 6.65×10^{10}

Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[54]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

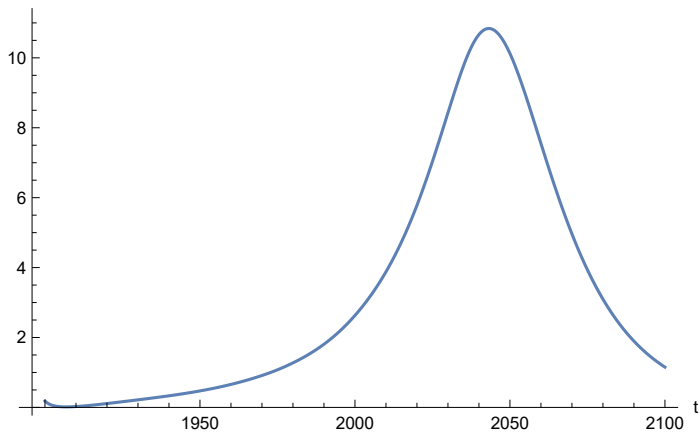
```
In[55]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 511.592
Minimum is 87.4451
```

Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Industrial_Investment1.Cons_Ind_Out_PC.y"}]]
Maximum is 138.222
Minimum is 9.05278
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

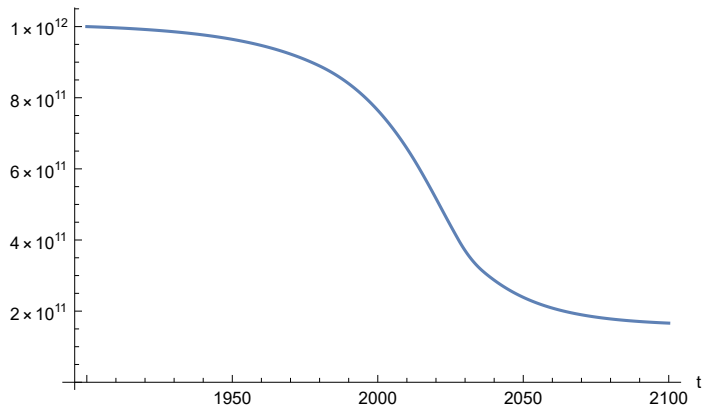
Maximum is 10.8395

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

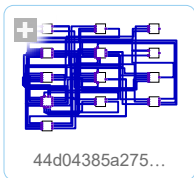
Out[59]=



APPENDIX 2. Effect of setting `t_policy_year` to 1970, Benchmark Scenario 1, Experiment 2

Change the value of `t_policy_year` to 1970, execute the resulting scenario, and plot various variables.

```
In[60]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
Out[60]=
```



```
In[61]:= testsim1970 = SystemModelSimulate[newmysim1970]
Out[61]=
```

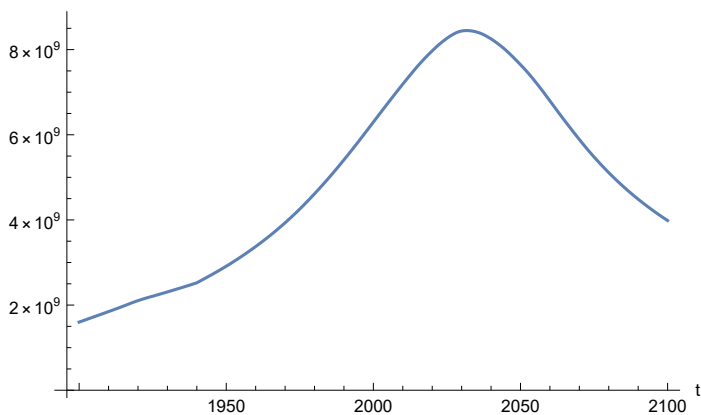
```
SystemModelSimulationData [ { Model: W44d04385a275494eb1bd241d128c3417
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  } ]
```

Show the value of `t_policy_year`.

```
In[62]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
Out[62]= {t_policy_year → 1970}
```

Plot the world population, people.

```
In[63]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[63]=
```



Find max and min of y values.

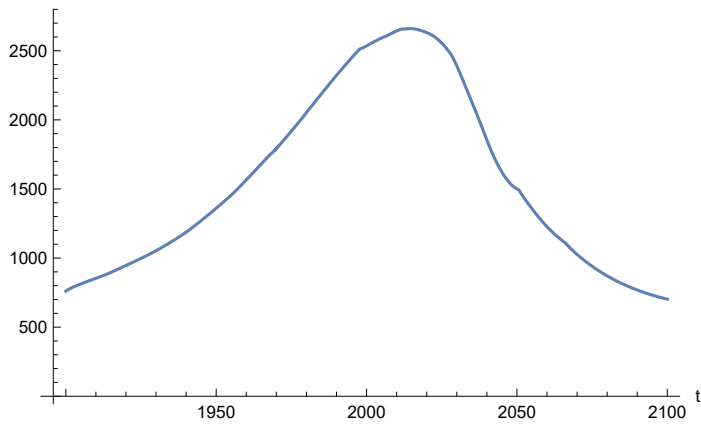
```
In[64]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.44751×10^9

Minimum is 1.6×10^9

```
In[65]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
```

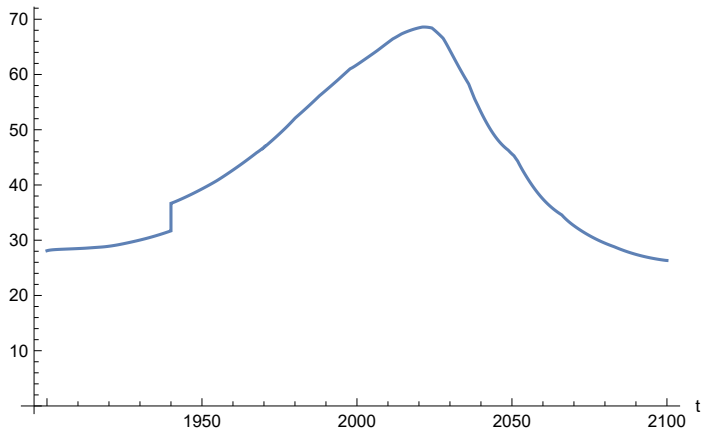
Out[65]=



Plot life expectancy, in years.

```
In[66]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
```

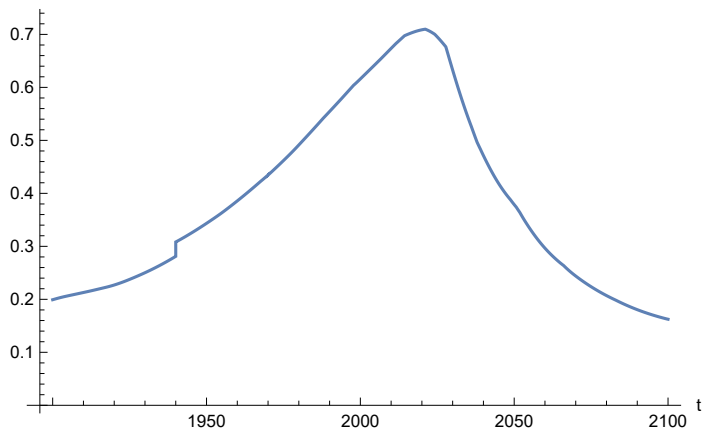
Out[66]=



Plot the human welfare index.

```
In[67]:= SystemModelPlot[testsim1970,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

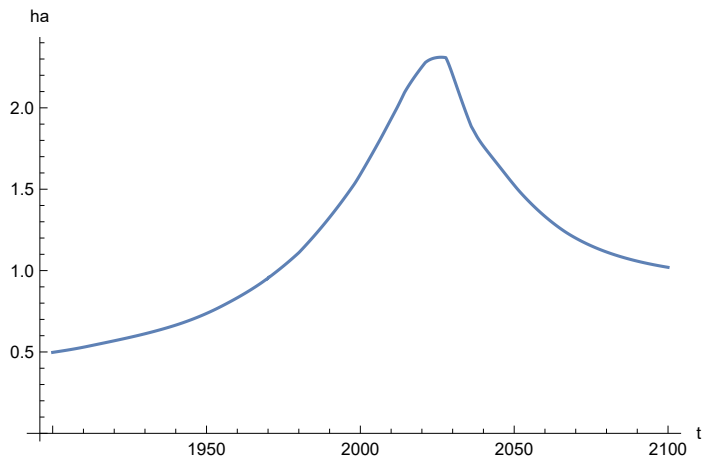
Out[67]=



Plot the human ecological footprint, in hectares.

```
In[68]:= SystemModelPlot[testsim1970,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```

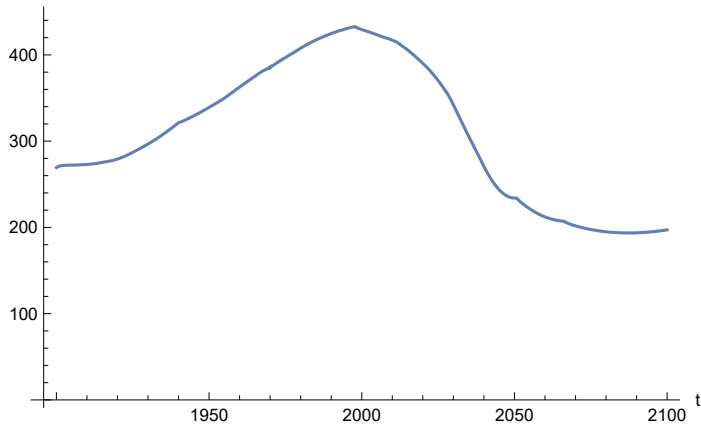
Out[68]=



Plot per capita food production, kg/year.

In[69]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]**

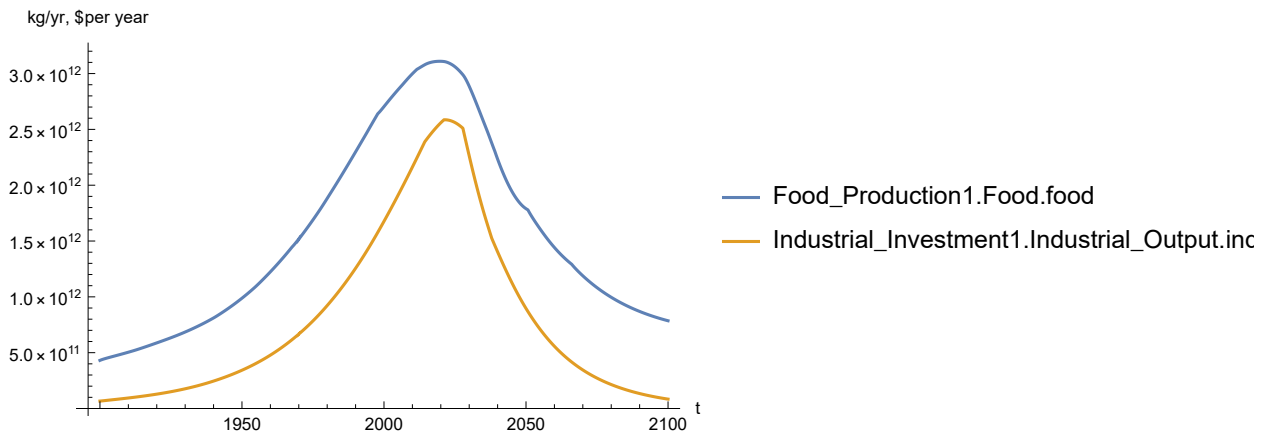
Out[69]=



Plot total food production (kg/yr) and industrial output (in dollars).

In[70]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

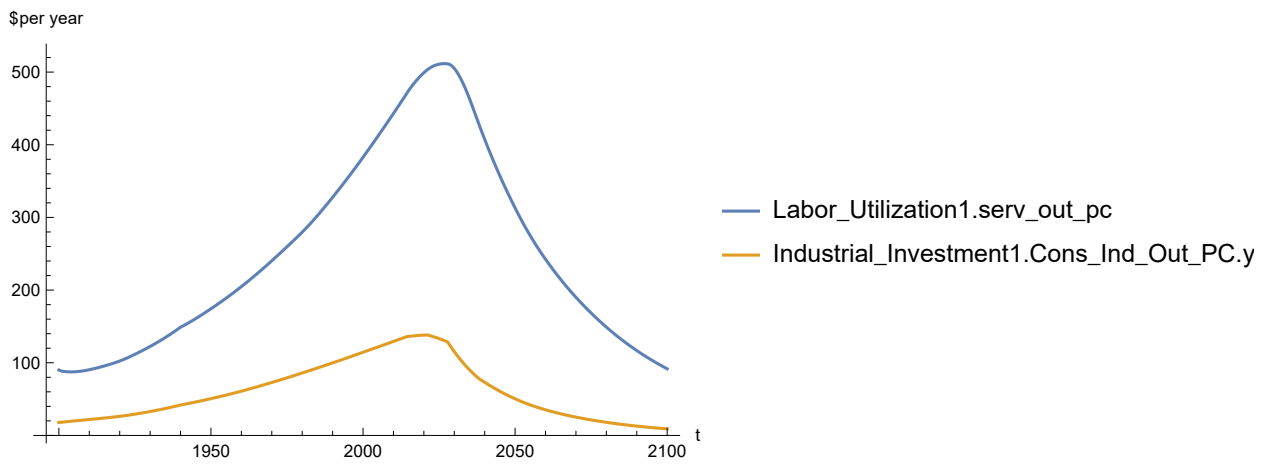
Out[70]=



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[71]:= SystemModelPlot[testsim1970,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[71]=



Find max and min of y values.

```
In[72]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

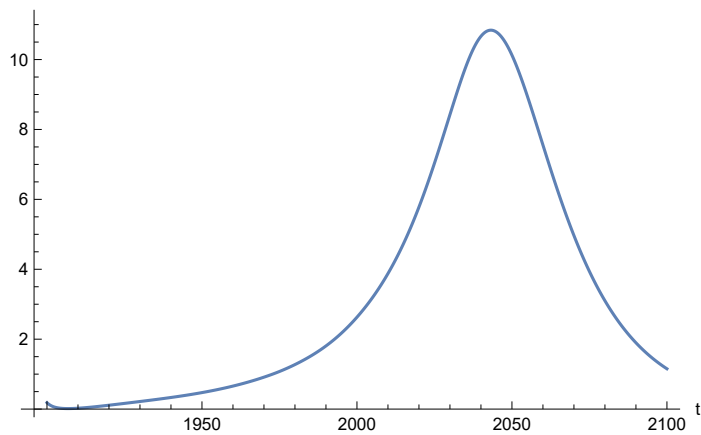
Maximum is 511.604

Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[73]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[73]=



Find max and min of y values.

```
In[74]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

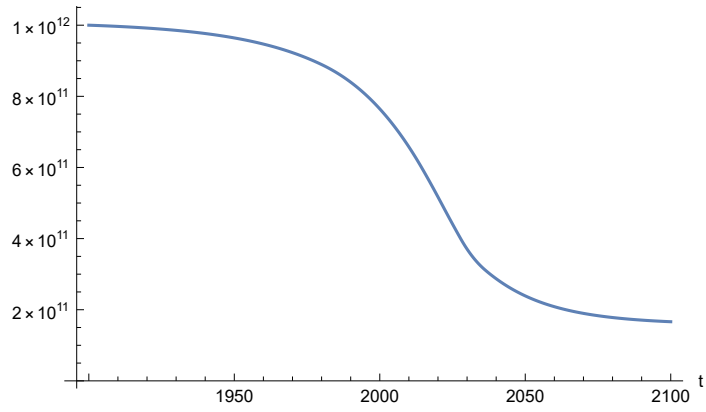
Maximum is 10.8402

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[75]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[75]=

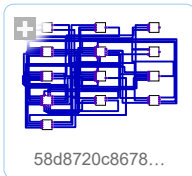


APPENDIX 3. Benchmark Scenario 1, $t_{\text{policy_year}} = 2025$. Experiment 3.

Change the value of the air pollution effect multiplier switch time $t_{\text{policy_year}}$, to calendar year 2025, and execute the resulting scenario, plotting the variables shown in Figure 2.

```
In[76]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```

```
Out[76]=
```



```
In[77]:= testsim = SystemModelSimulate[newmysim]
```

```
Out[77]=
```

```
SystemModelSimulationData [  Model: W58d8720c86784e689bdcb49358bfa2ce  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of $t_{\text{policy_year}}$.

```
In[78]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
```

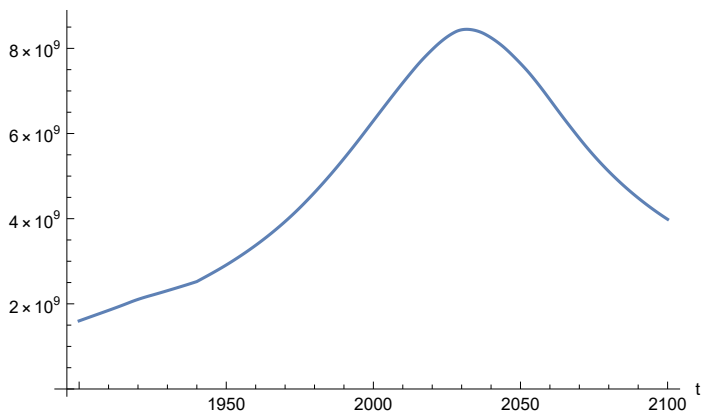
```
Out[78]=
```

```
{t_policy_year → 2025}
```

Plot the world population, people.

```
In[79]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[79]=
```

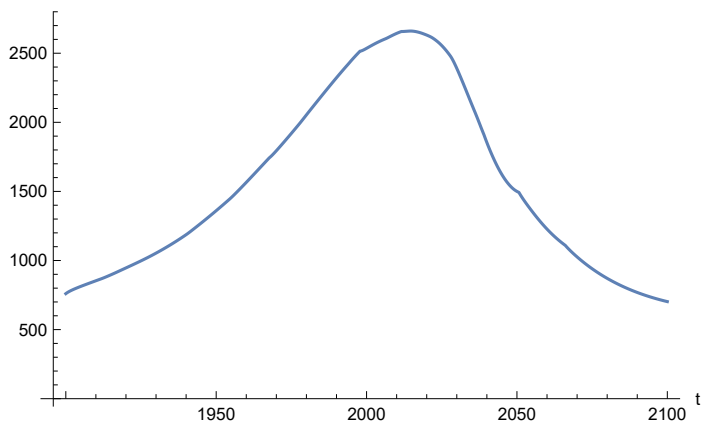


Find max and min of y values.

```
In[80]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.4473 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

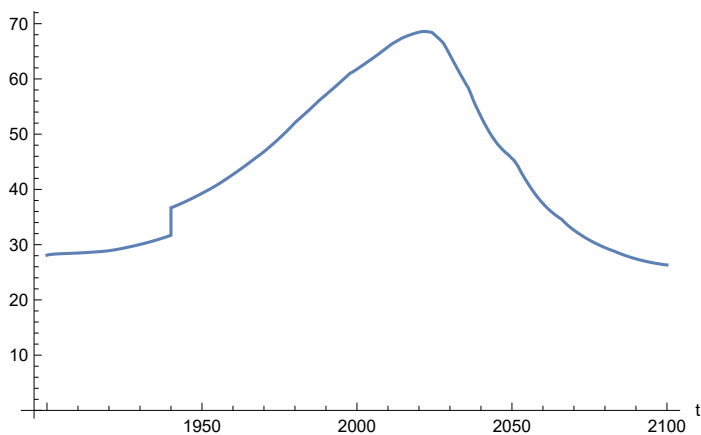
Plot land yield.

```
In[81]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[81]=
```



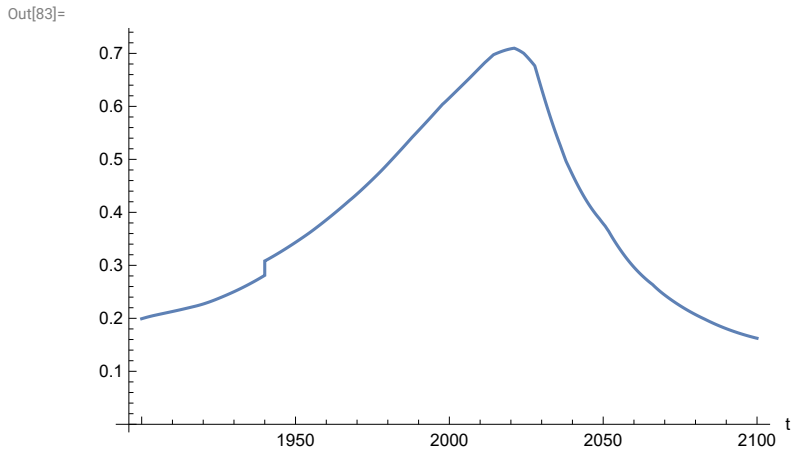
Plot life expectancy, in years.

```
In[82]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[82]=
```



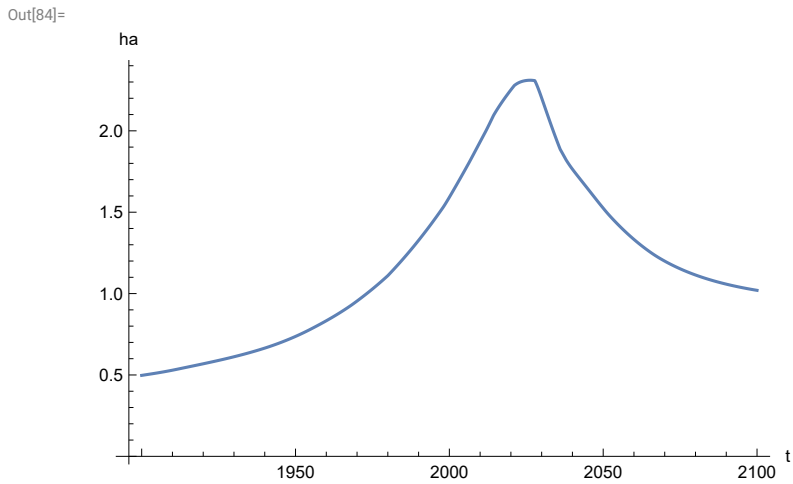
Plot the human welfare index.

```
In[83]:= SystemModelPlot[testsim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



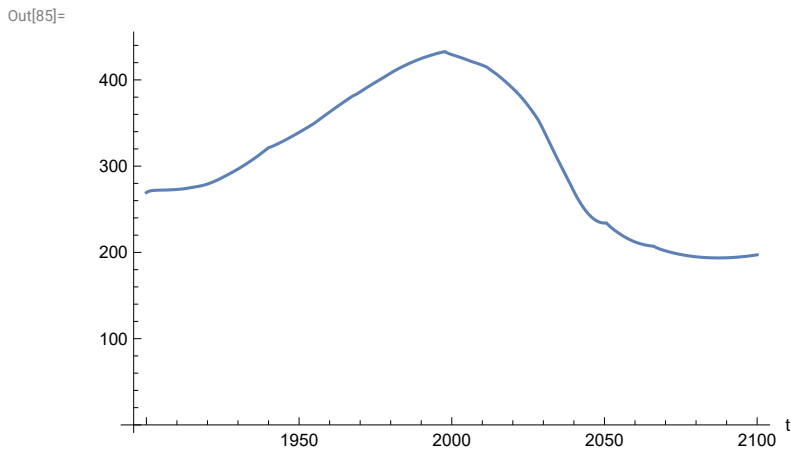
Plot the human ecological footprint, in hectares.

```
In[84]:= SystemModelPlot[testsim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



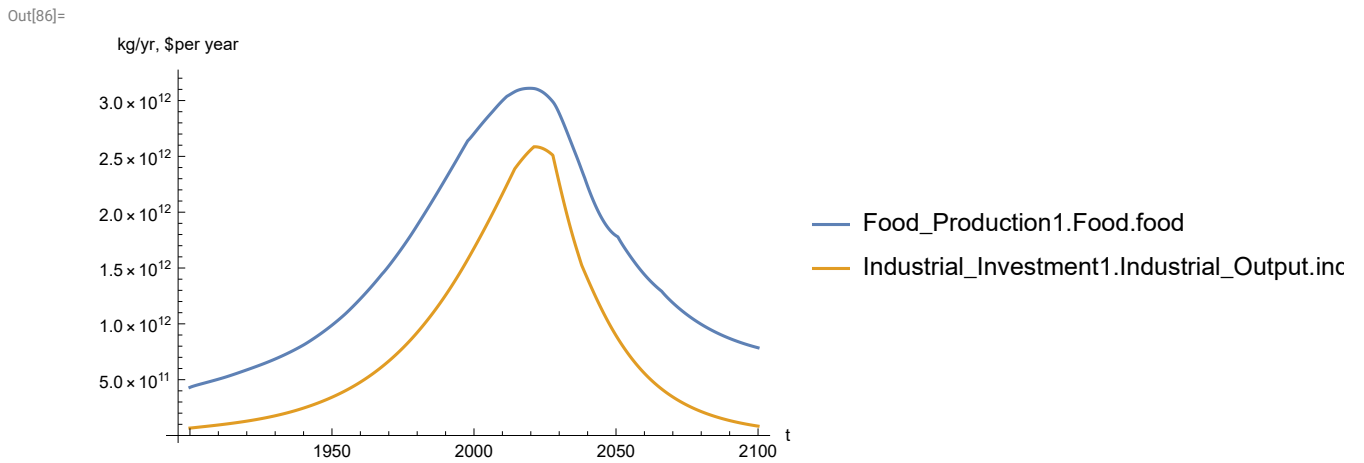
Plot per capita food production, kg/year.

In[85]:= **SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]**



Plot total food production (kg/yr) and industrial output (in dollars).

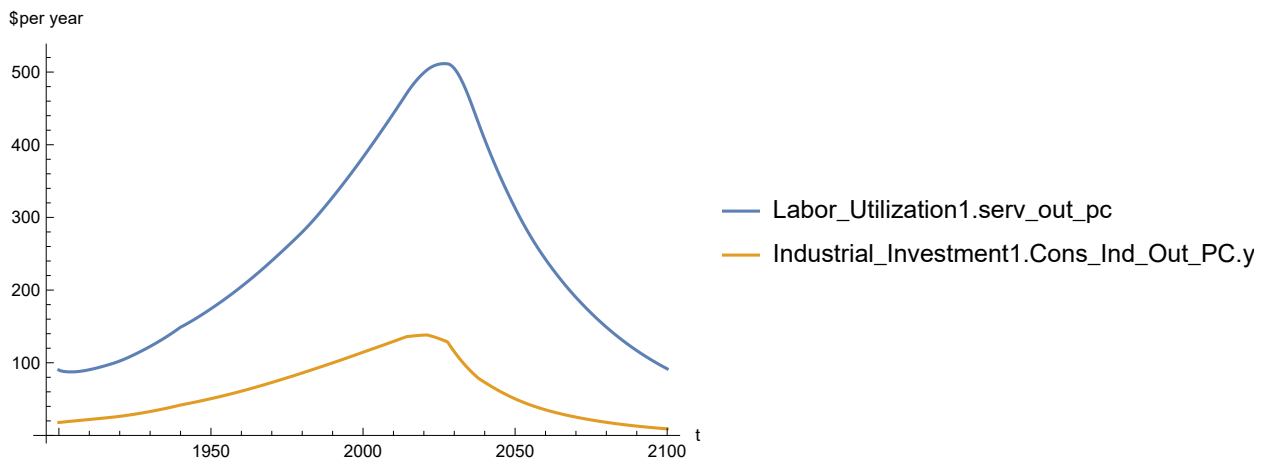
In[86]:= **SystemModelPlot[testsim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**



Plot consolidated industrial output per capita (dollars/year).

```
In[87]:= SystemModelPlot[testsim,
{"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[87]=



Find max and min of y values.

```
In[88]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
```

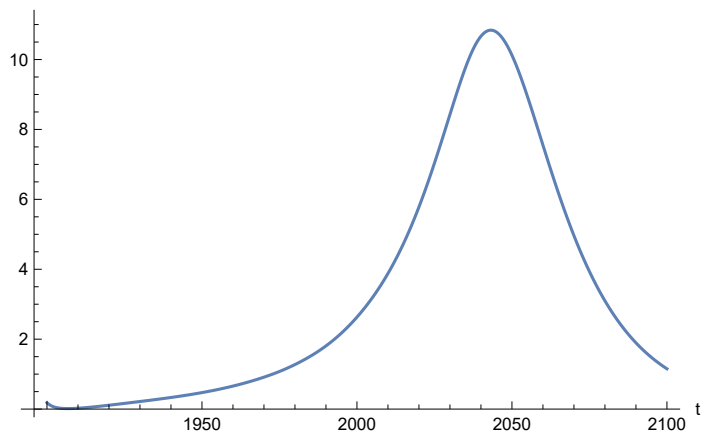
Maximum is 511.592

Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[89]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[89]=



Find max and min of y values.

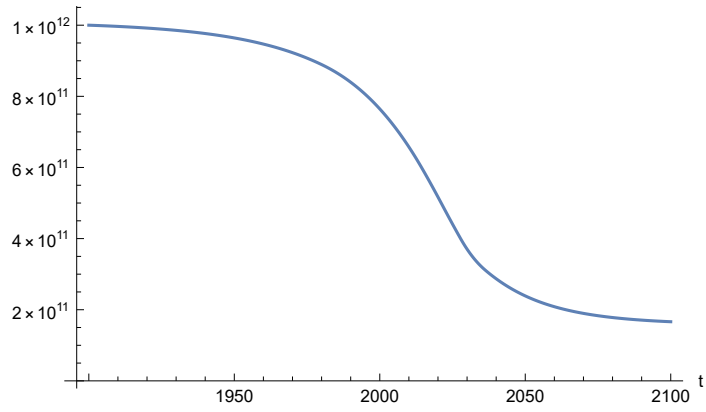
```
In[90]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 10.8395

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[91]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[91]=
```



**APPENDIX 4. BENCHMARK SCENARIO 1, Experiment 4. LE = LE/1.001, t_policy_year = 1970.
Last modified: 21 July 2022/0830 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

```
In[ ]:= RangeData[data_] := data[[1]][[4]][[3]];
```

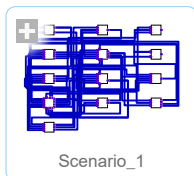
Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

```
In[ ]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 1 (“Business as Usual”).

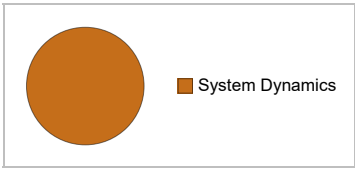
```
In[ ]:=  
mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_1"]
```

Out[]:=



```
In[*]:= mysummary = mysim["Summary"]
```

```
Out[*]=
```

Model	SystemDynamics.WorldDynamics.World3.Scenario_1
Description	Original WORLD3 model
Simulation Interval	True
Plot	0
Control Center	106
Background Color	True
Simulation Start	265
Simulation End	265
Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[*]=
```

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[*]=
```

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[*]=
```

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[*]=
```

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[*]=
```

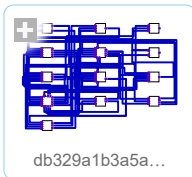
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[*]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[*]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[*]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[*]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[*]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[*]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

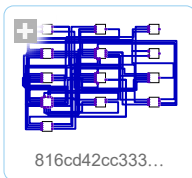
```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[ ]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[ ]:=
```



Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim1970]
```

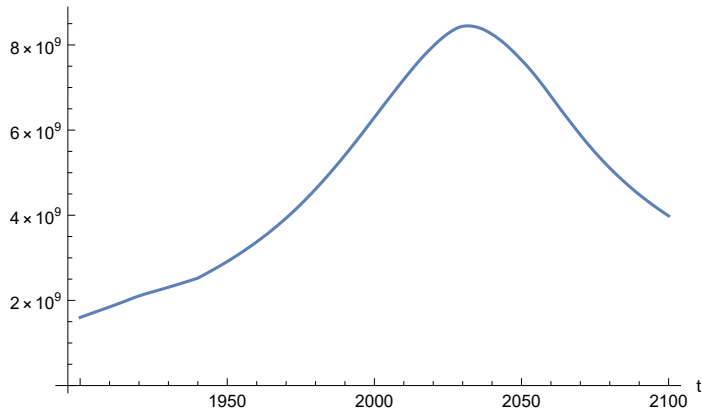
```
Out[ ]:=
```

```
SystemModelSimulationData [  Model: W816cd42cc3334a7abdfd7df2f42f7f5f  
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

Out[]:=



Find max and min of population values.

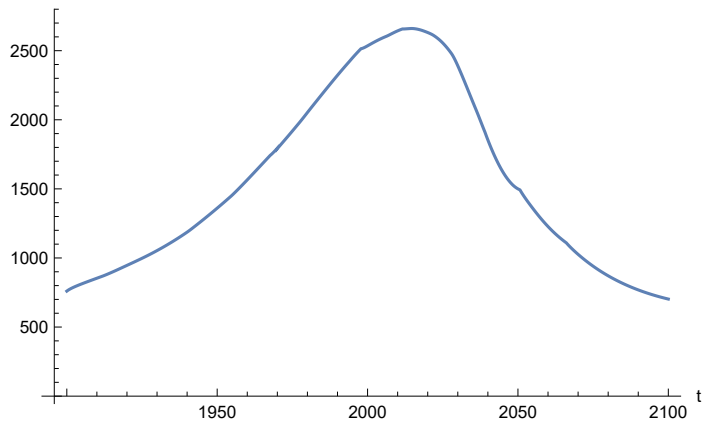
```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.44751×10^9

Minimum is 1.6×10^9

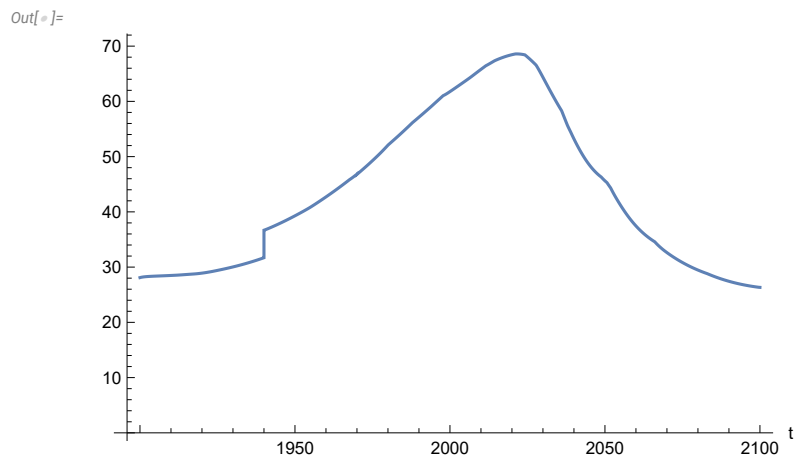
```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

Out[]:=



Plot life expectancy, years.

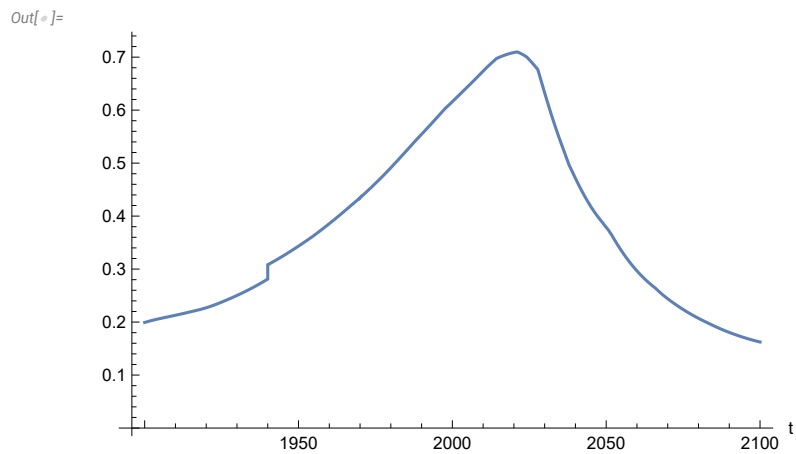
```
In[*]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[*]:=
```

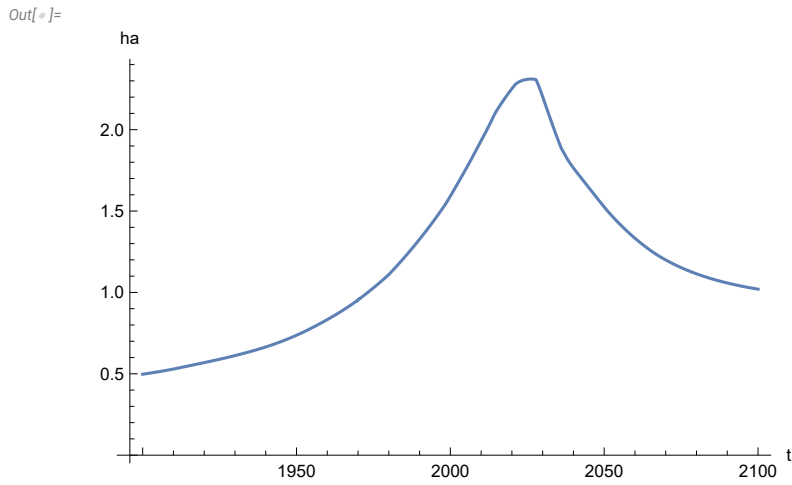
Plot human welfare index.

```
In[*]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



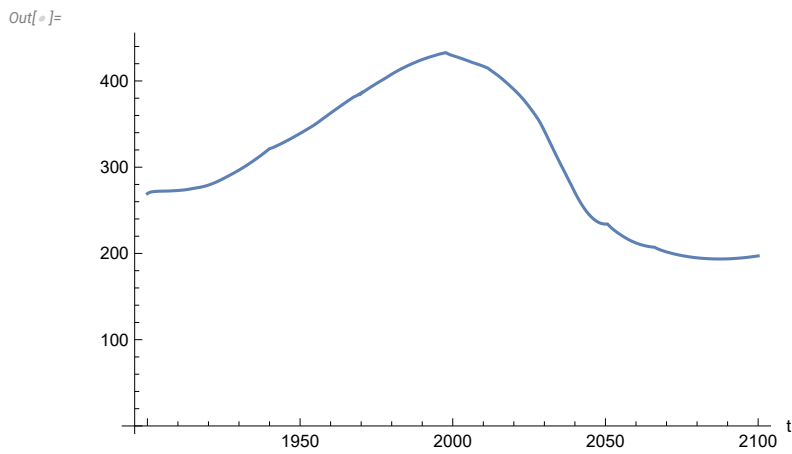
Plot per capita ecological footprint, hectares.

```
In[ ]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

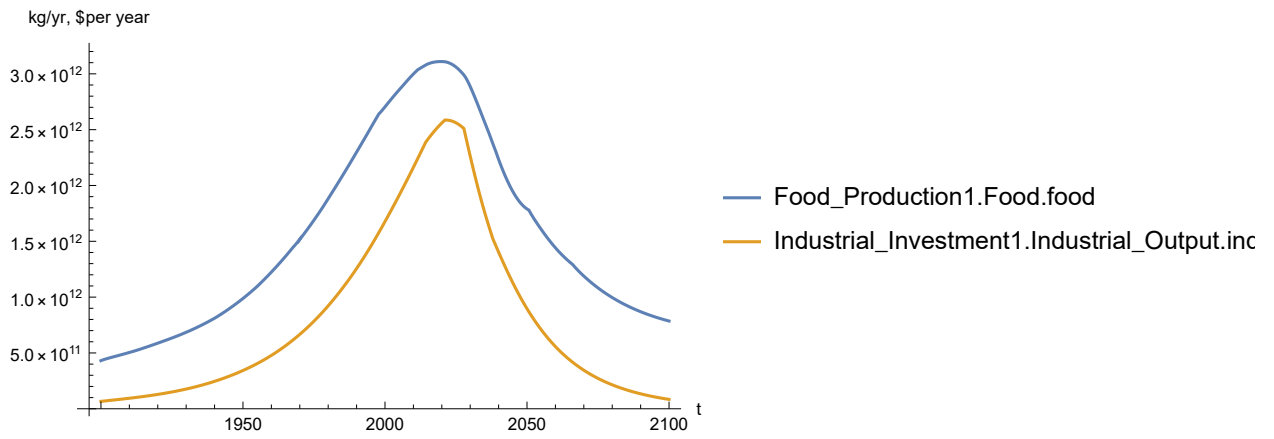
```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

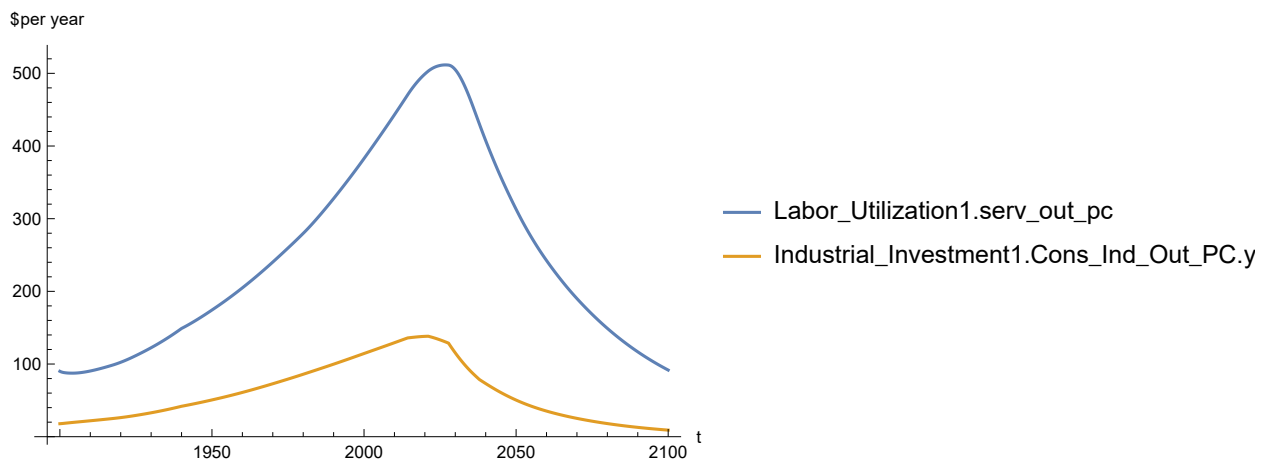
Out[]:=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[ ]:= SystemModelPlot[basesim, {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[]:=



Find max and min of y values.

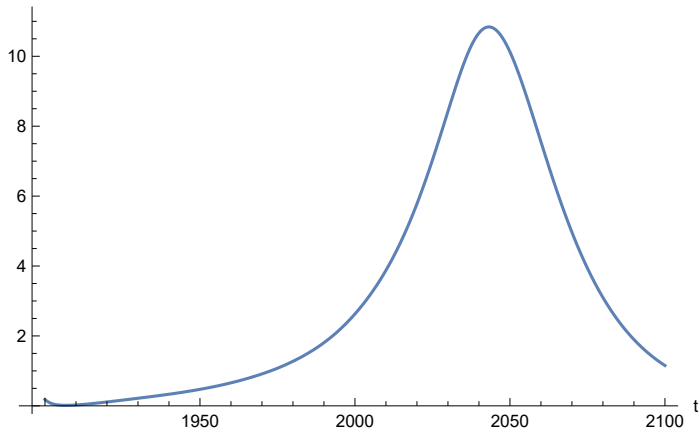
```
In[ ]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 511.604

Minimum is 87.4451

Plot persistent pollution index.

```
In[ ]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[ ]:=
```

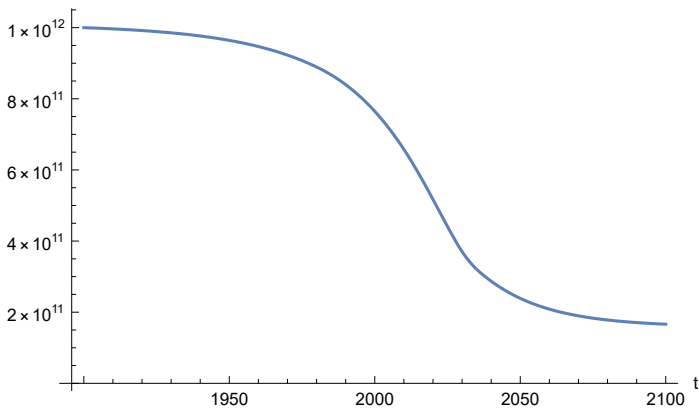


Find max and min of y values.

```
In[ ]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.8402
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[ ]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
Out[ ]:=
```

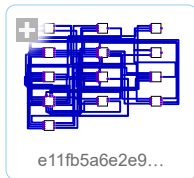


APPENDIX 5. LE/1.001, t_policy_year = 2025. Baseline Scenario 1, Experiment 5.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure default _Serv_2.y_vals

```
In[ ]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[]:=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[]:=

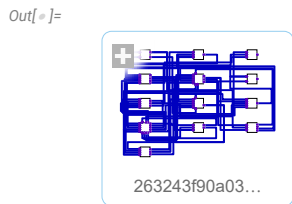
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set t_policy_year to 2025.

```
In[ ]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```



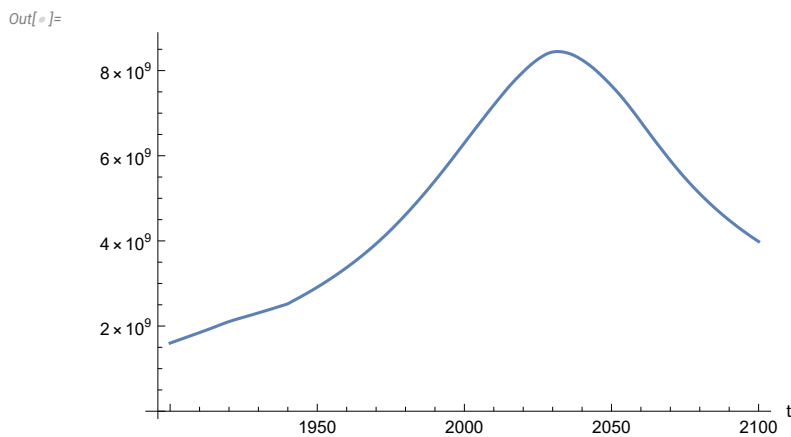
Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim2025]
```

```
Out[ ]:= SystemModelSimulationData [
  Model: W263243f90a034969b893fdee75494052
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



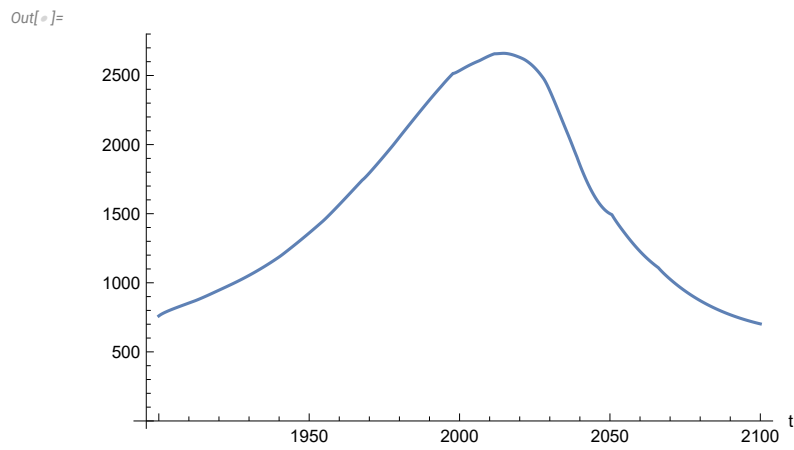
Find max and min of population values.

```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.4473×10^9

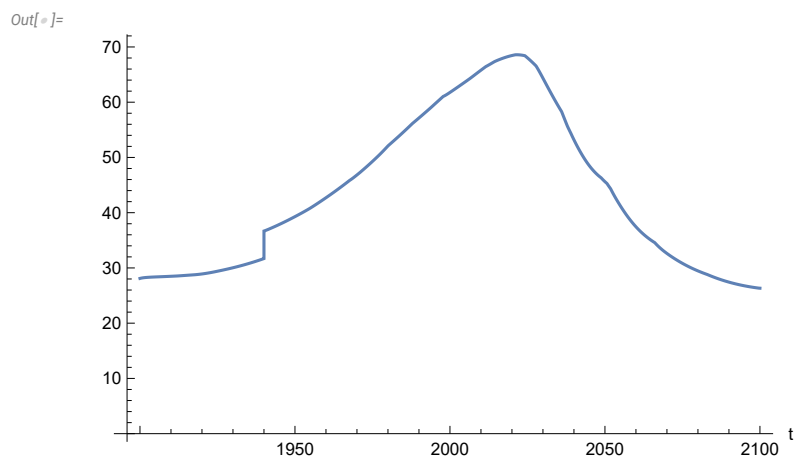
Minimum is 1.6×10^9

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```



Plot life expectancy, years.

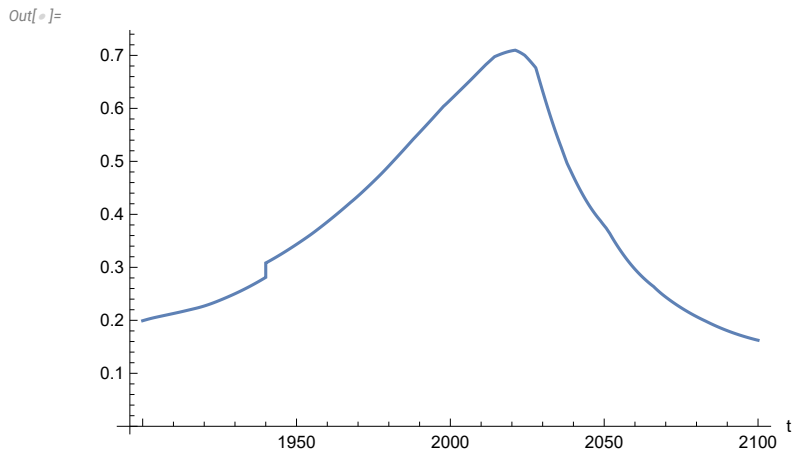
```
In[ ]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[ ]:=
```

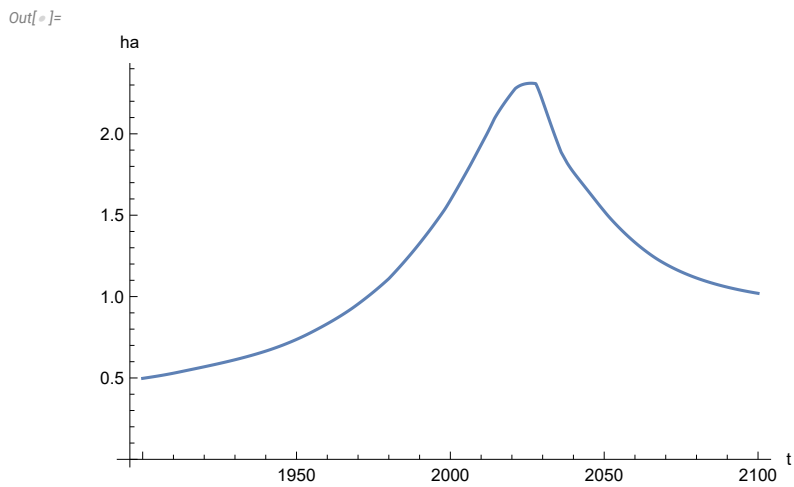
Plot human welfare index.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



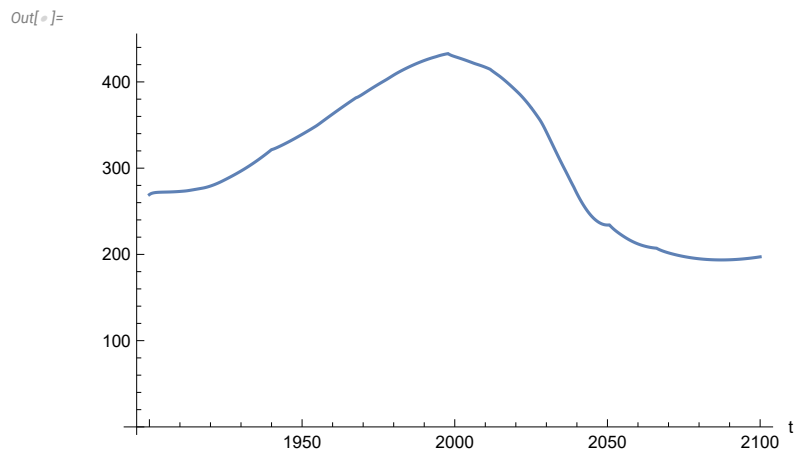
Plot per capita ecological footprint, hectares.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



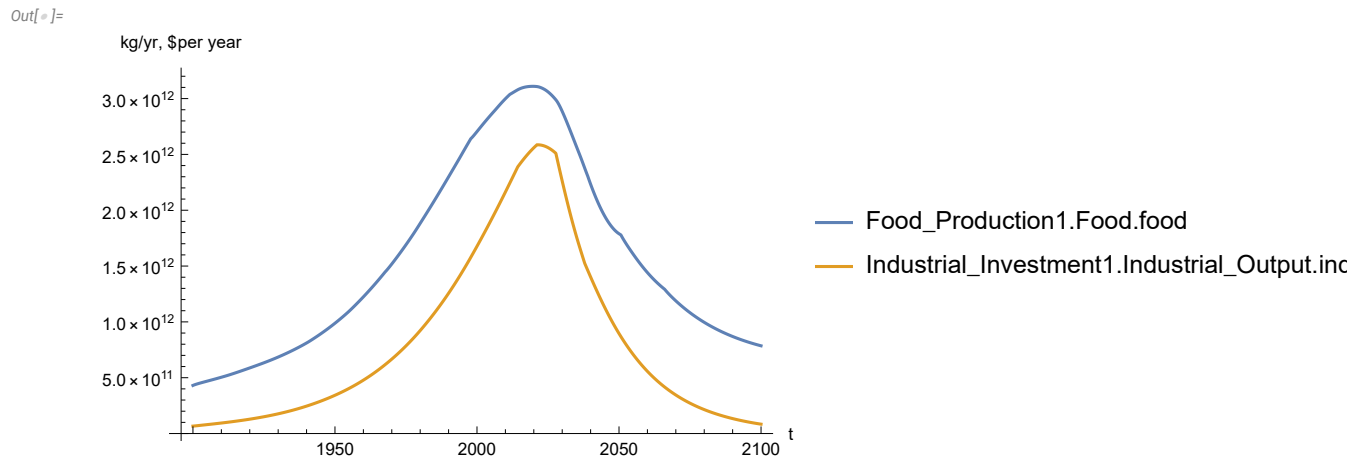
Plot food production per capita (kg/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



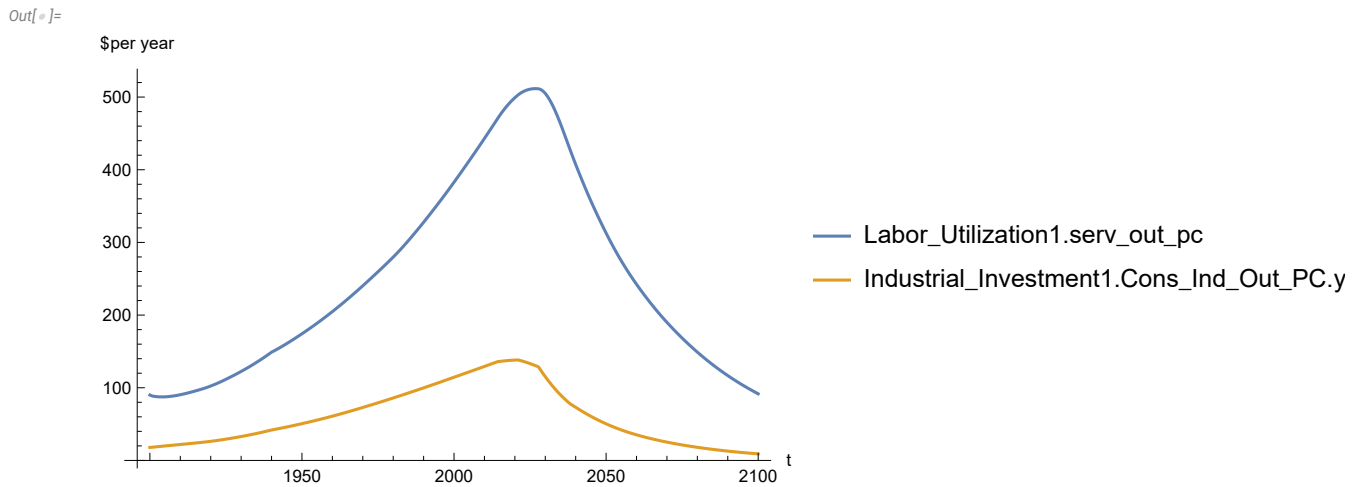
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[*]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

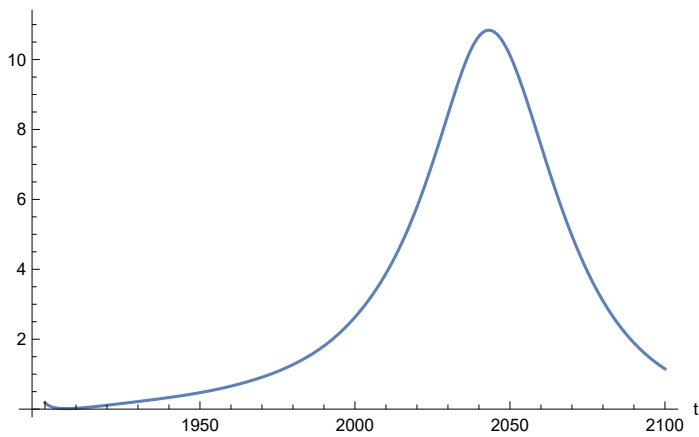


Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 511.592
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[*]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[*]=
```

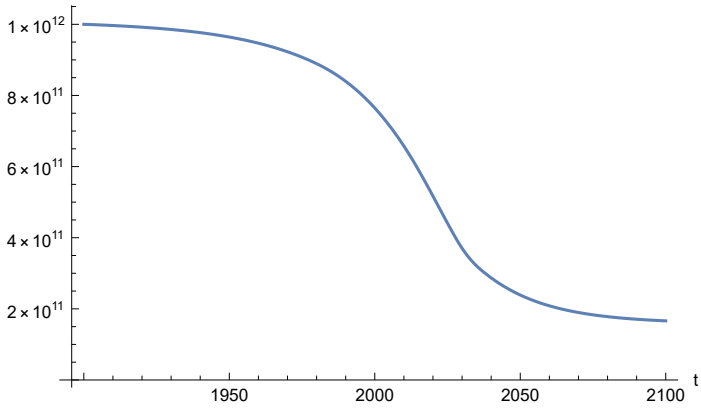


Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.8395
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[*]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[*]=
```

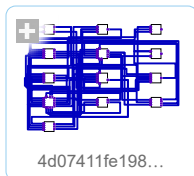


APPENDIX 6. LE/1.01, t_policy_year = 1970. Baseline Scenario 1, Experiment 5.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[*]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[*]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[*]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[*]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[*]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[*]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[*]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[*]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[*]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[*]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[*]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[*]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[*]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[*]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

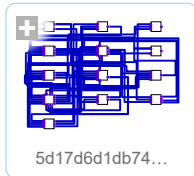
```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set t_policy_year to 1970.

```
In[ ]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[ ]:=
```



Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim1970]
```

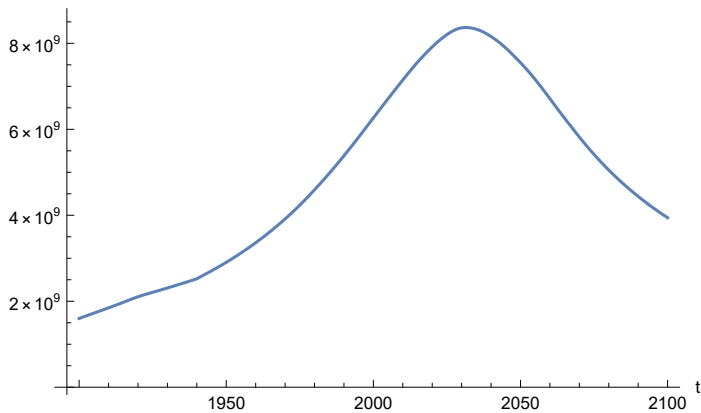
```
Out[ ]:=
```

```
SystemModelSimulationData [  Model: W5d17d6d1db744a7cac89377065f842bd
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[ ]:=
```



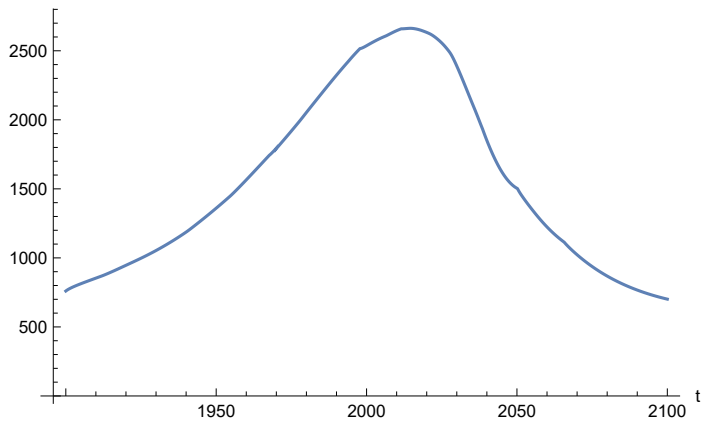
Find max and min of population values.

```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.36756 × 109
```

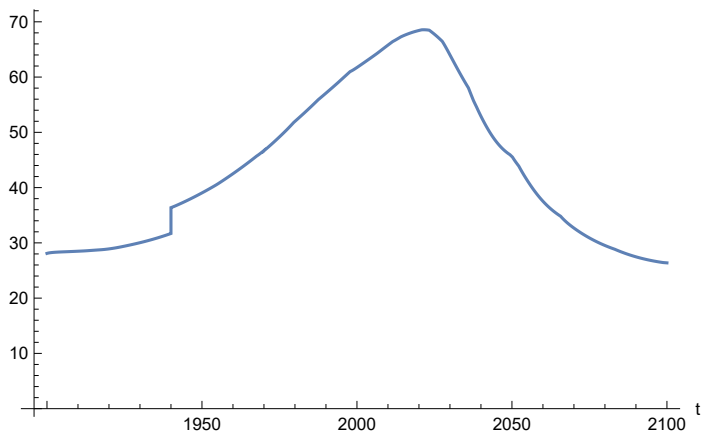
```
Minimum is 1.6 × 109
```

```
In[*]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[*]=
```



Plot life expectancy, years.

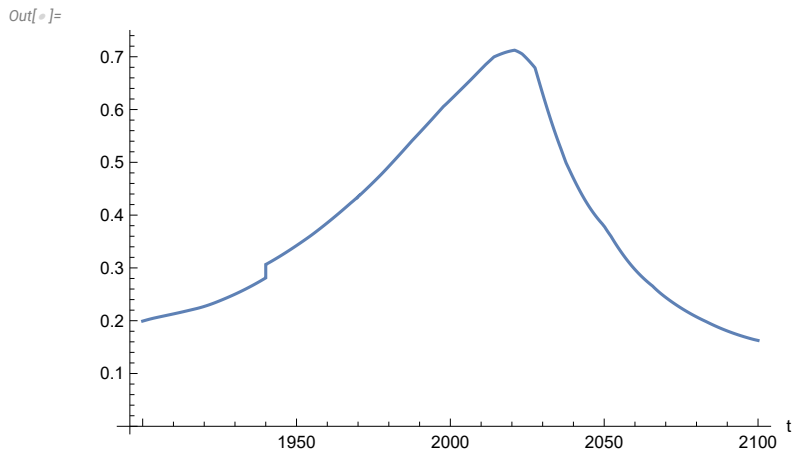
```
In[*]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[*]=
```



```
In[*]:=
```

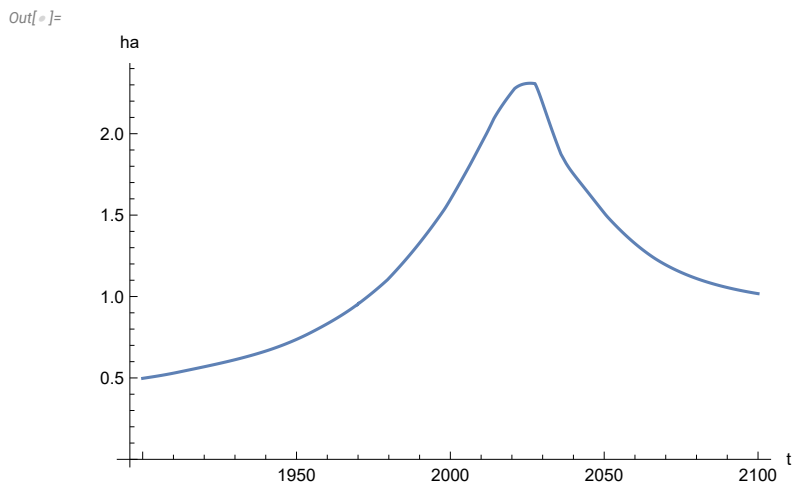
Plot human welfare index.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

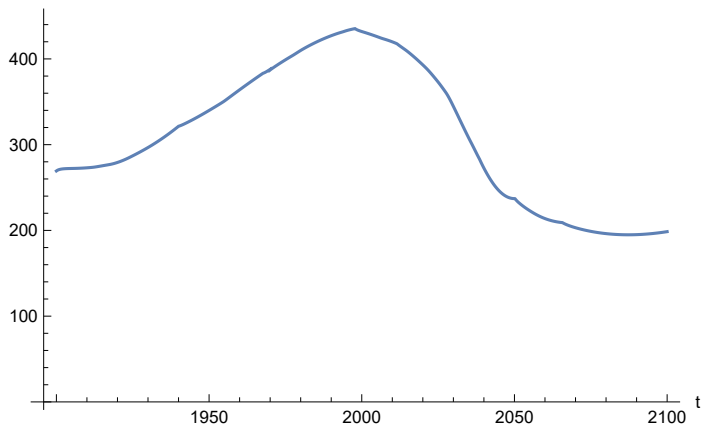
```
In[*]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

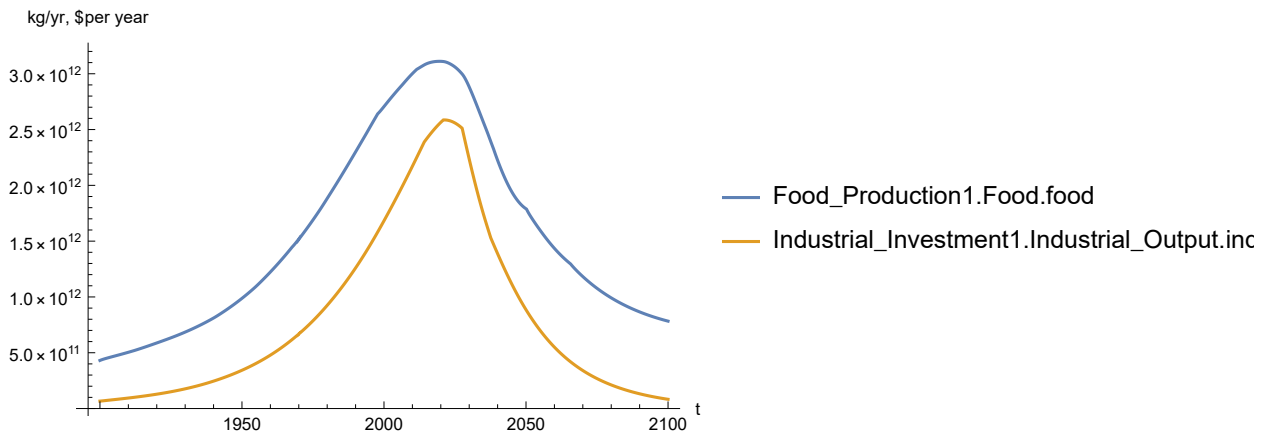
```
Out[ ]:=
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

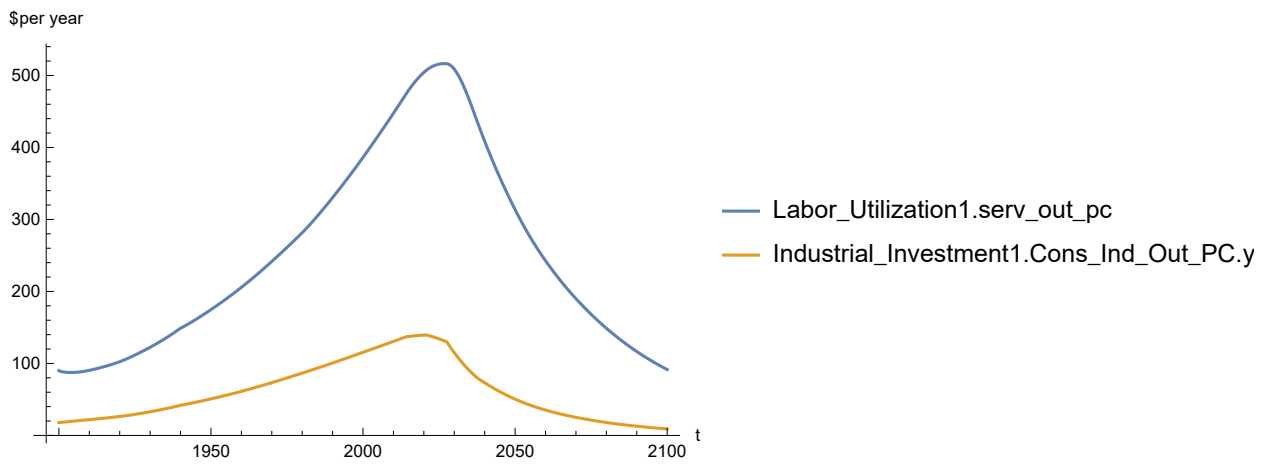
```
Out[ ]:=
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[*]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[*]=



Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

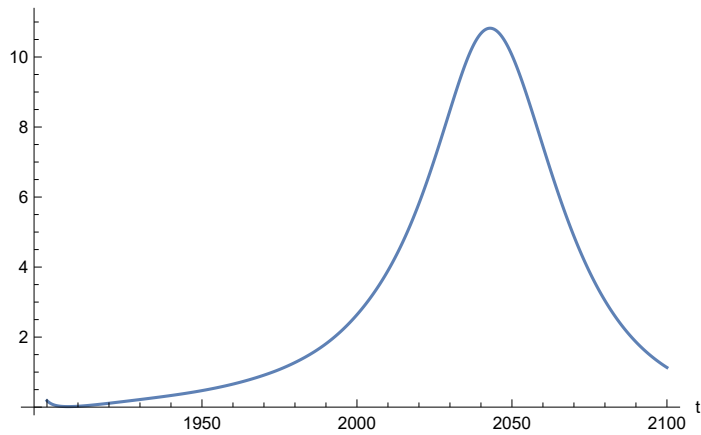
Maximum is 516.406

Minimum is 87.4451

Plot persistent pollution index.

```
In[*]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[*]=



Find max and min of y values.

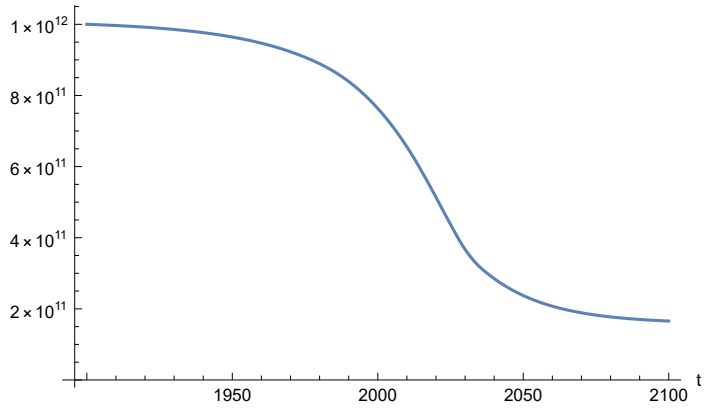
```
In[*]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 10.8223

Minimum is 0.0150765

Plot non-renewable resources remaining.

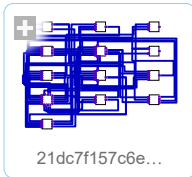
```
In[*]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[*]=
```



APPENDIX 7. Baseline Scenario 1, Experiment 7. LE = LE/1.01, t_policy_year = 2025.

```
In[ ]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}} |>]
```

Out[]:=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[]:=

{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[]:=

{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[]:=

{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[]:=

{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[]:=

{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[]:=

{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}

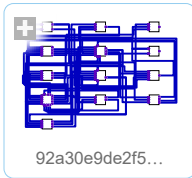
```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[]:=

{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}

Set `t_policy_year` to 2025.

```
In[ ]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}}>]
Out[ ]:=
```



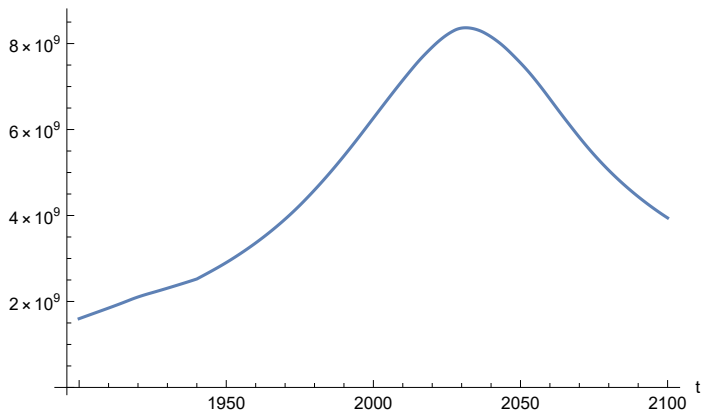
Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim2025]
Out[ ]:=
```

```
SystemModelSimulationData [ Model: W92a30e9de2f54ed2bb4beffecbc777ae
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

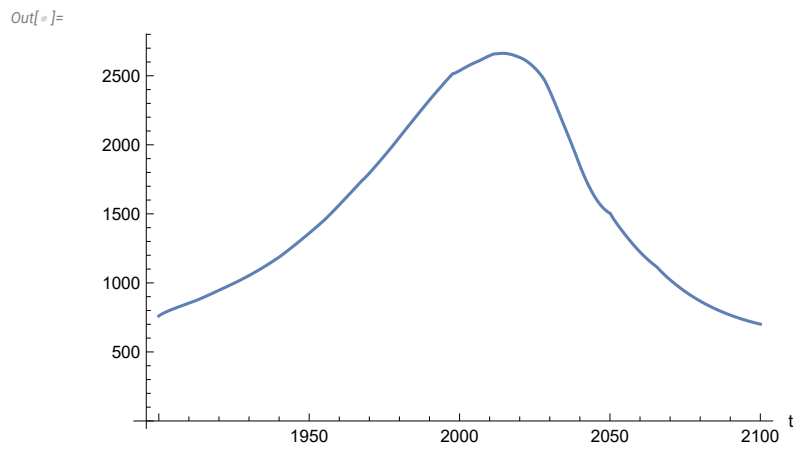
```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[ ]:=
```



Find max and min of population values.

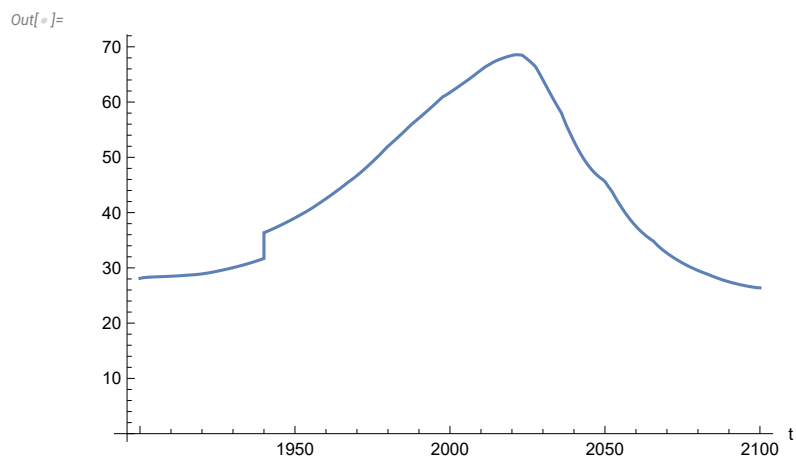
```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is 8.36735 × 109
Minimum is 1.6 × 109
```

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```



Plot life expectancy, years.

```
In[ ]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[ ]:=
```

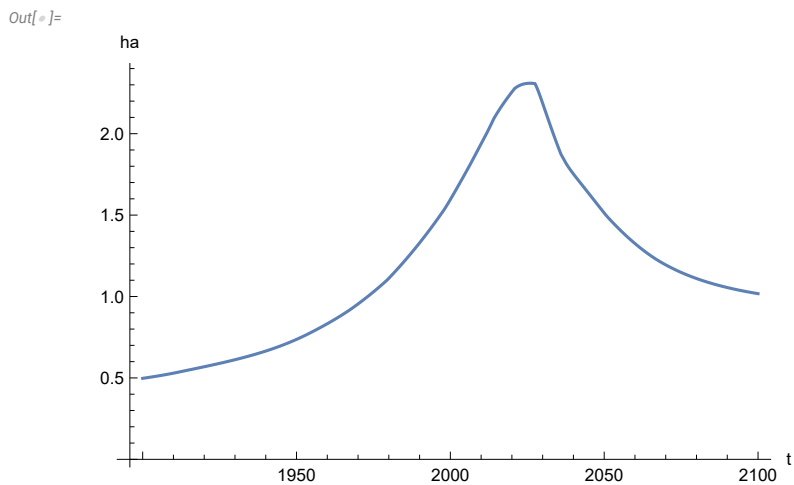
Plot human welfare index.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



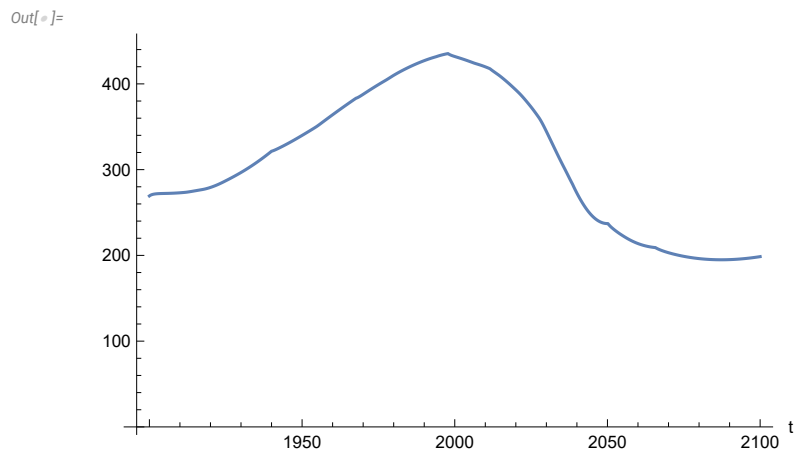
Plot per capita ecological footprint, hectares.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



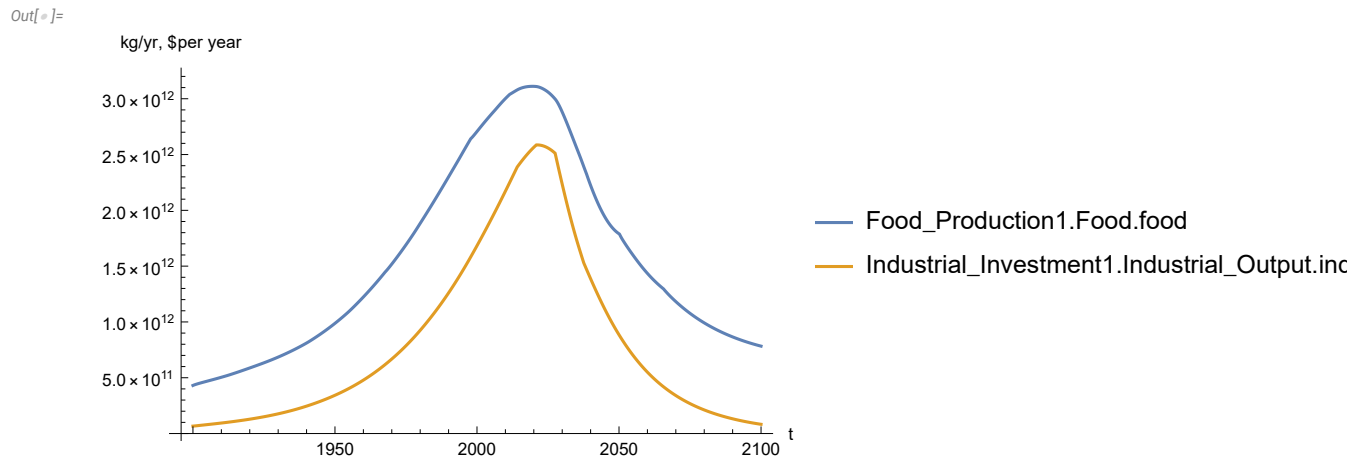
Plot food production per capita (kg/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



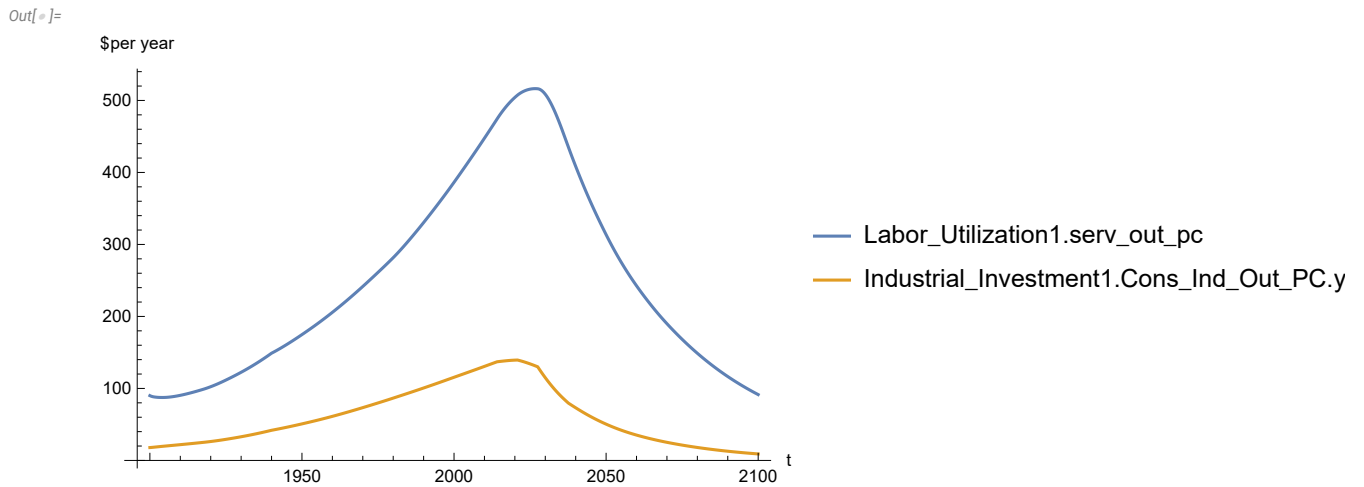
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[*]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

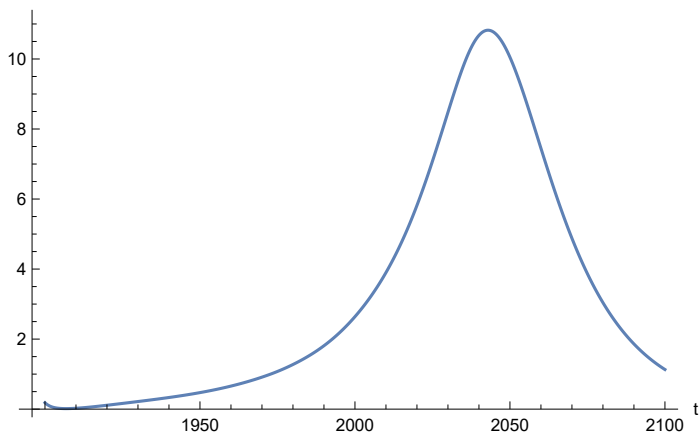


Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 516.393
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[*]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[*]=
```

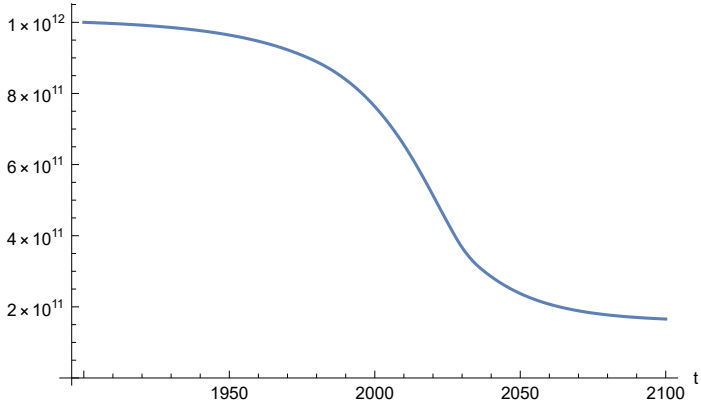


Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.8216
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[*]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[*]=
```



**APPENDIX 8. BENCHMARK SCENARIO 1, Experiment 8. $LE = LE/1.03$, $t_policy_year = 1970$.
Last modified: 22 July 2022/1215 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

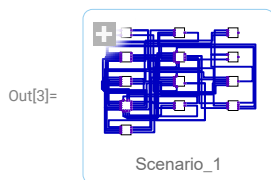
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

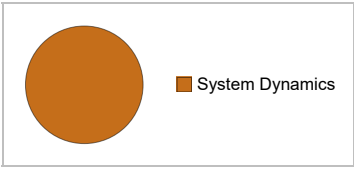
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 1 (“Business as Usual”).

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_1"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_1
	Description	Original WORLD3 model
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

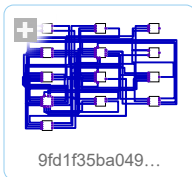
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

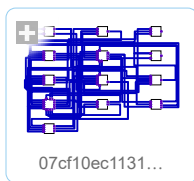
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

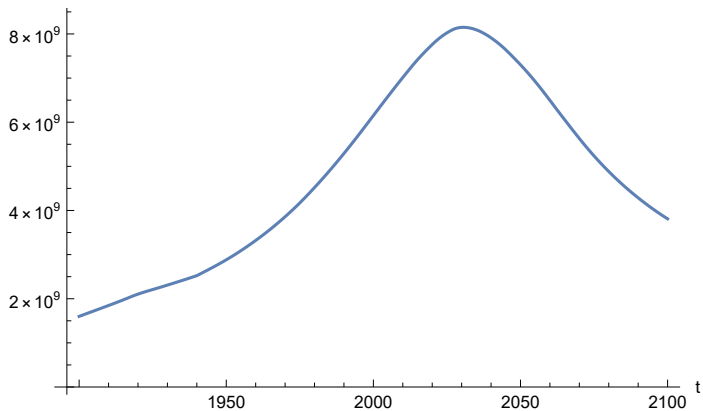
```
Out[21]=
```

```
SystemModelSimulationData [ {  Model: W07cf10ec113143d9a9332c9cfd5c8857  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  } ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

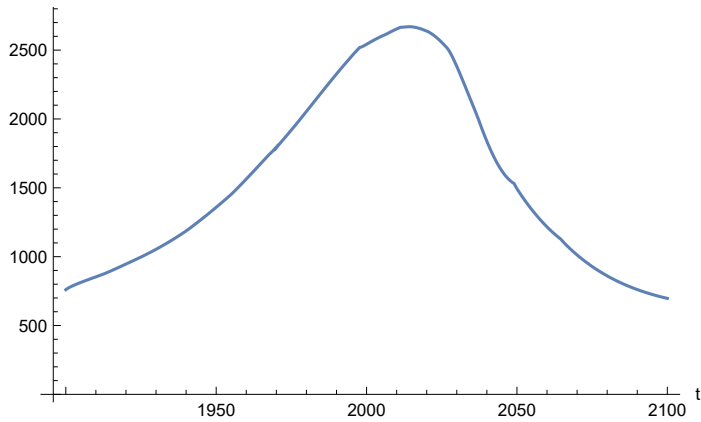
```
Out[22]=
```



Find max and min of population values.

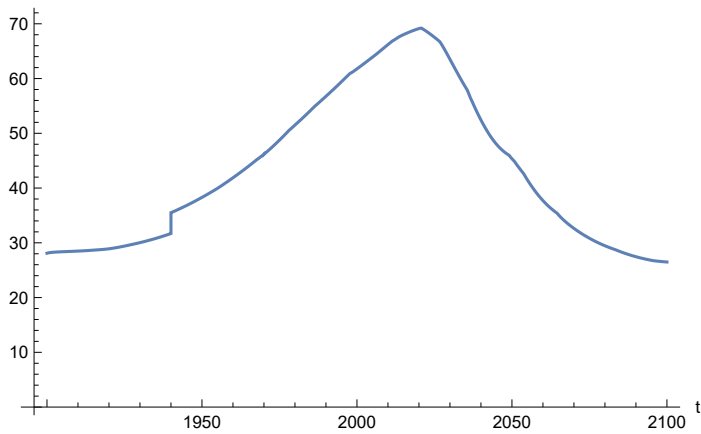
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.14996 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```

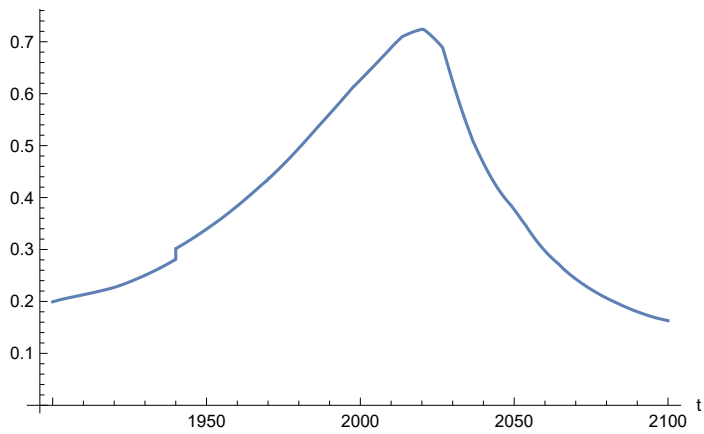


```
In[26]:=
```

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

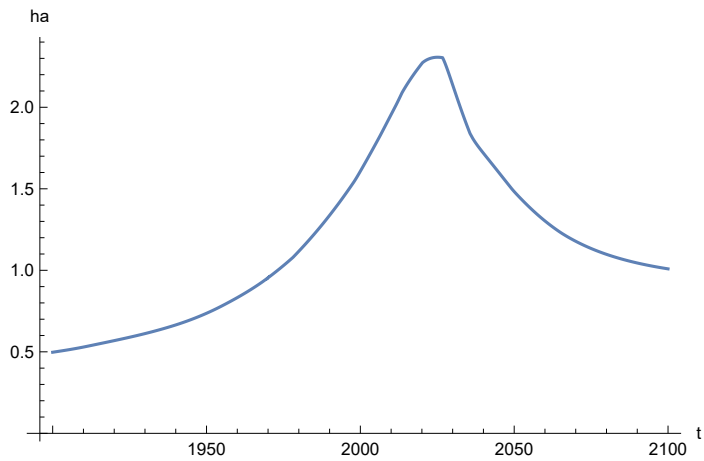
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```

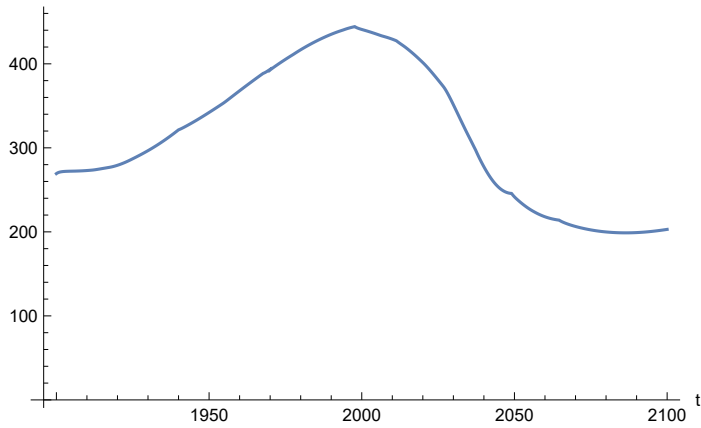
Out[28]=



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

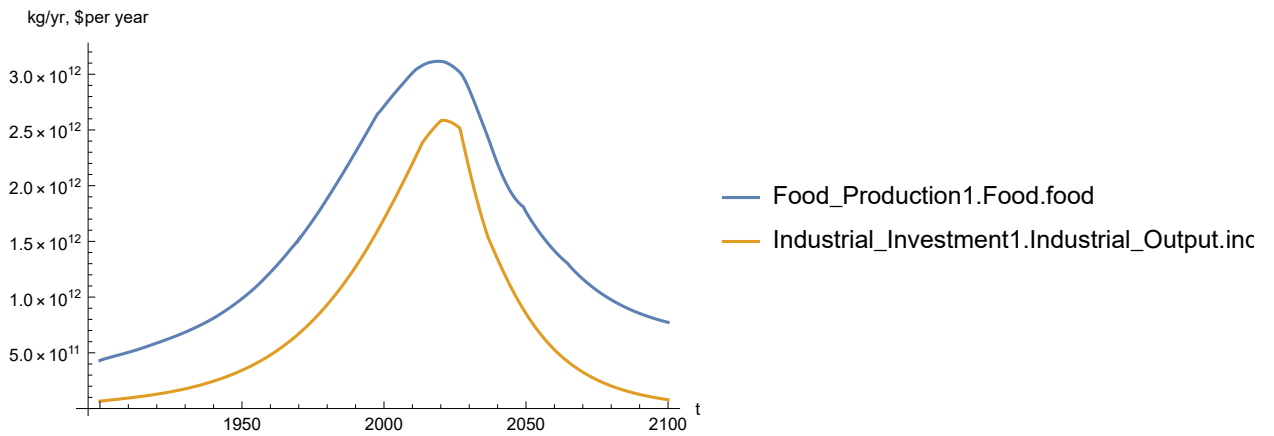
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

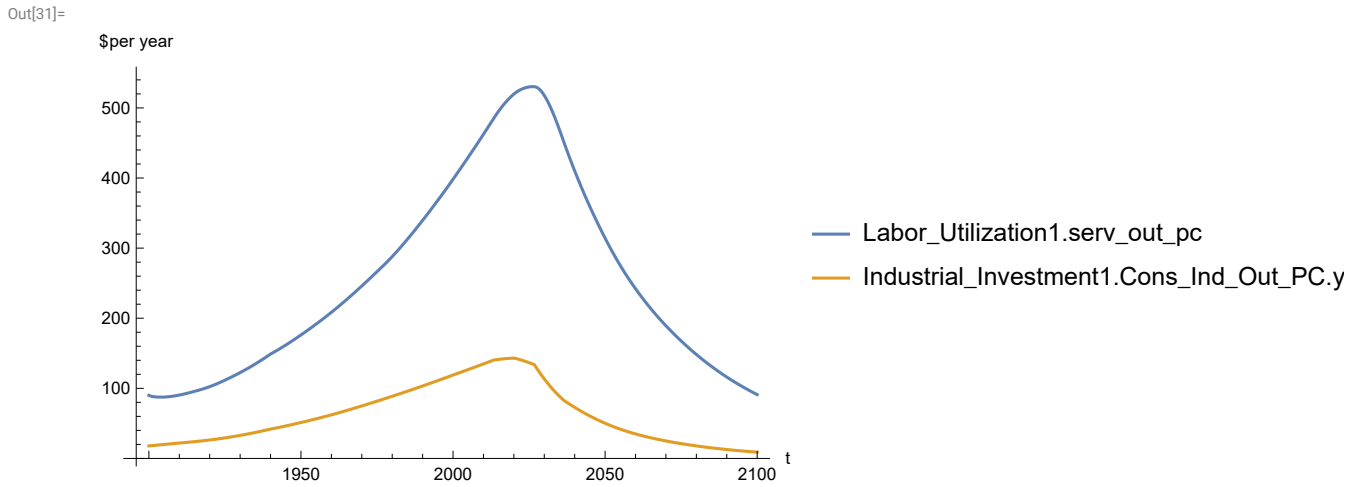
In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

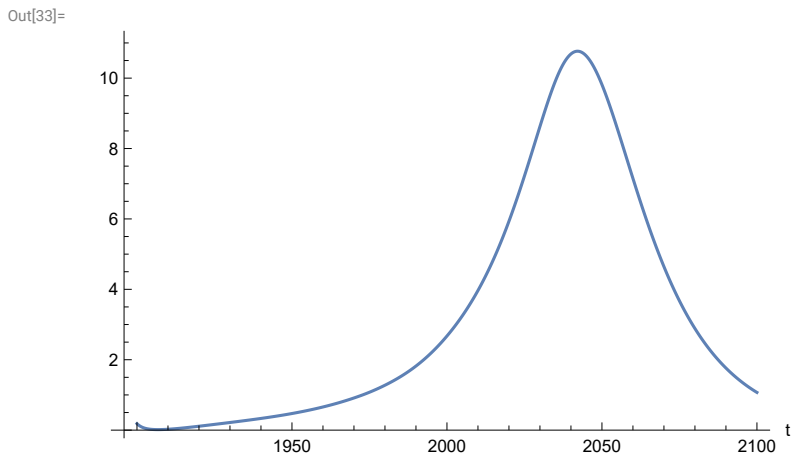


Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 530.331
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



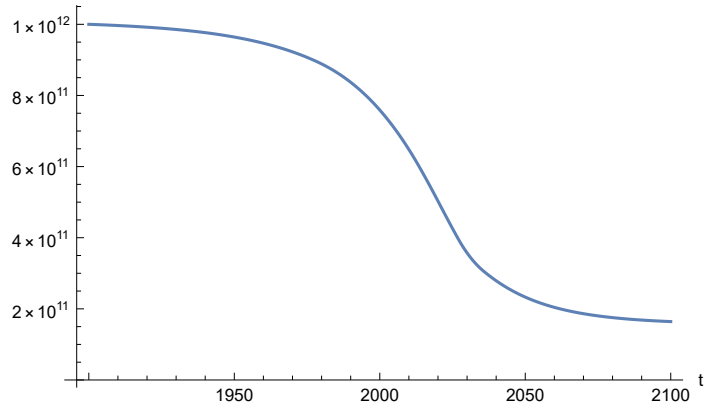
Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.7646
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

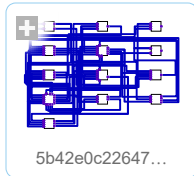


APPENDIX 9. LE/1.03, t_policy_year = 2025. Baseline Scenario 1, Experiment 9.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}} |>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

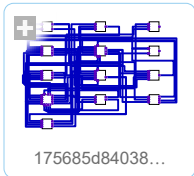
```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
```


```
Out[44]=
```



Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

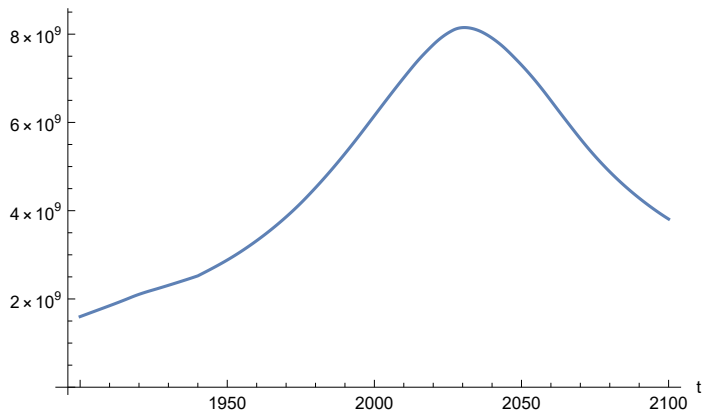
```
Out[45]=
```

```
SystemModelSimulationData [  Model: W175685d840384762b87a828d50005dbe  
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[46]=
```



Find max and min of population values.

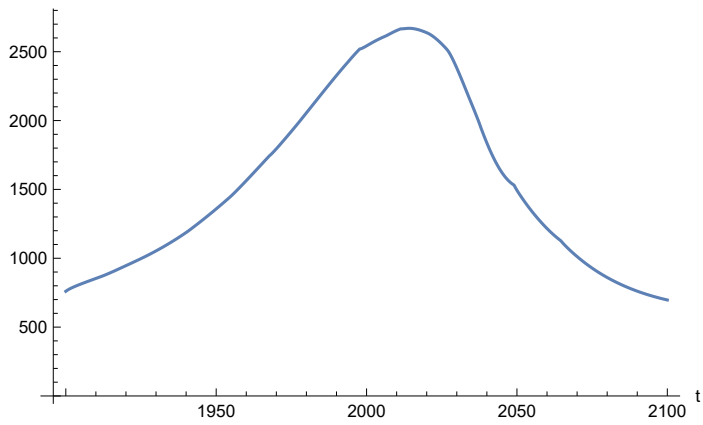
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.14979 × 109
```

```
Minimum is 1.6 × 109
```

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

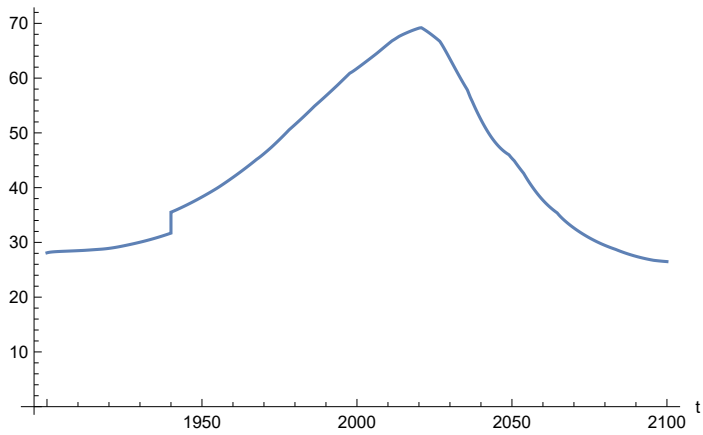
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

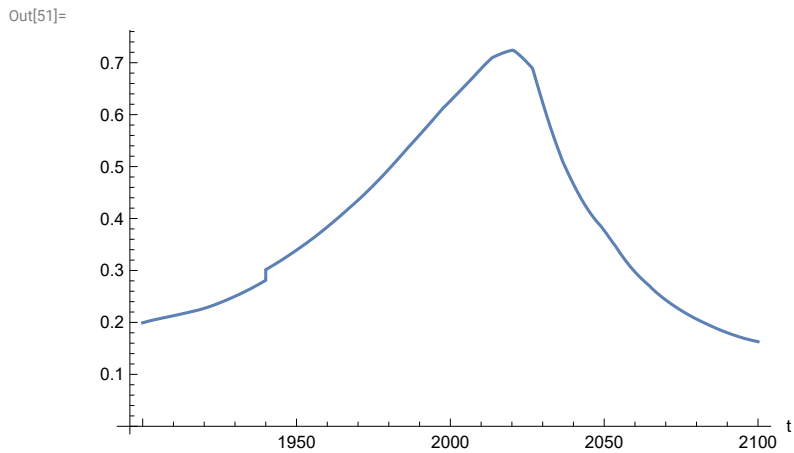
Out[49]=



In[50]=

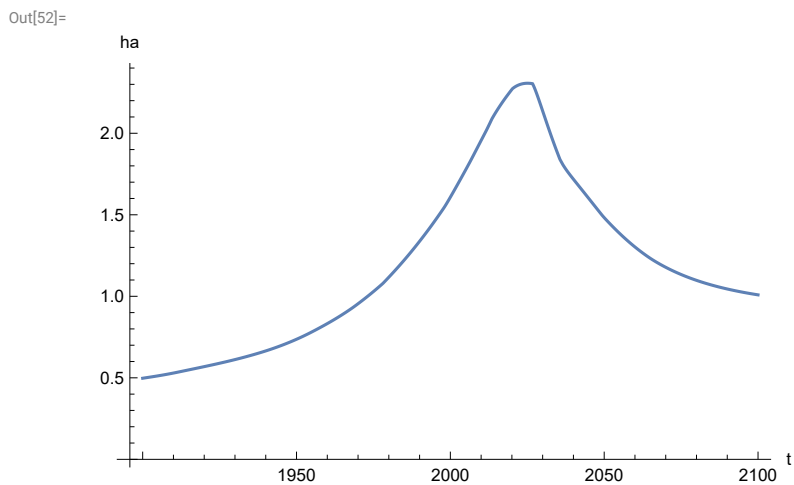
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

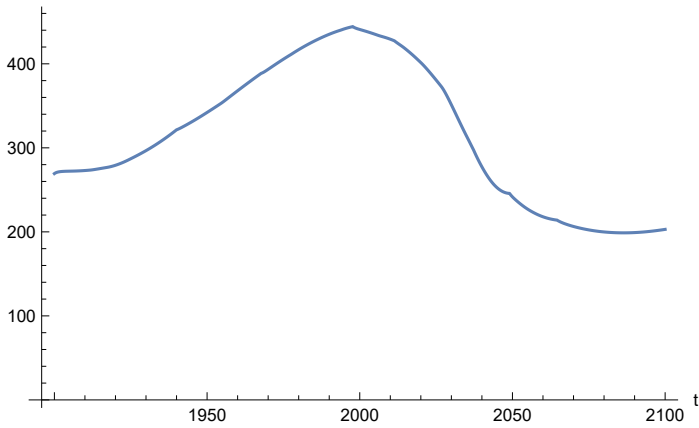
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

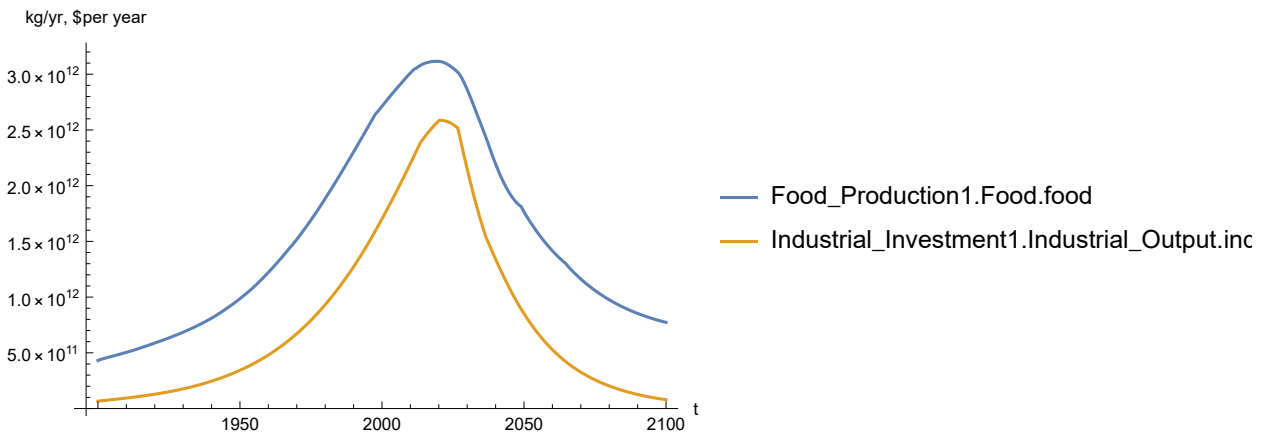
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

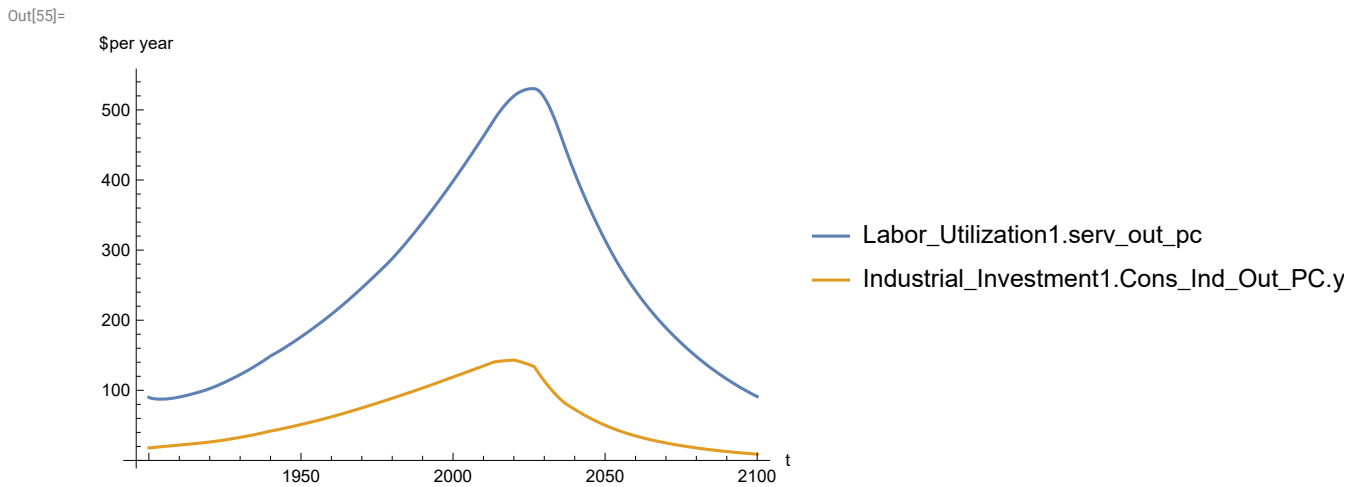
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

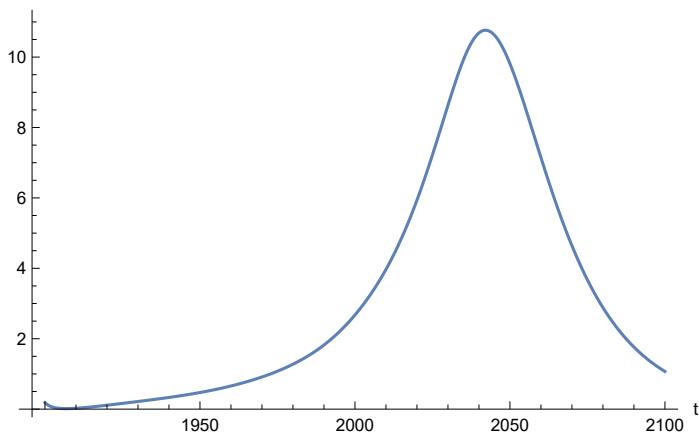


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 530.315
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



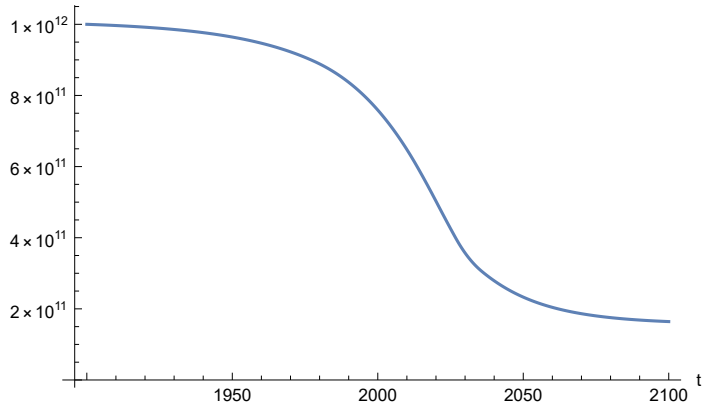
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.7639
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

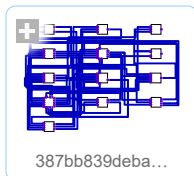


APPENDIX 10. LE/1.05, t_policy_year = 1970. Baseline Scenario 1, Experiment 10.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

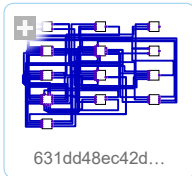
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

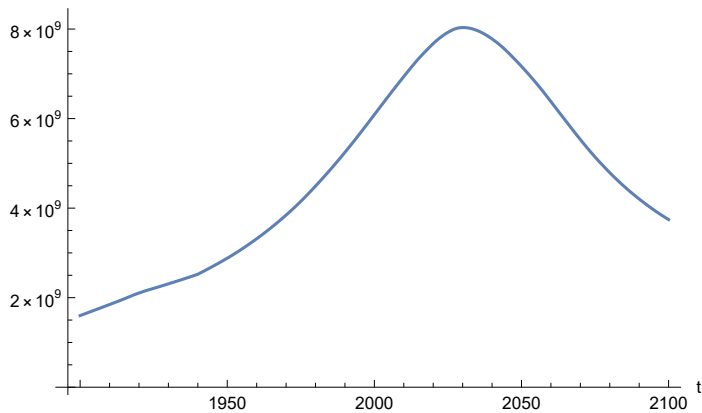
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W631dd48ec42d4943b14574983b8533ba  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

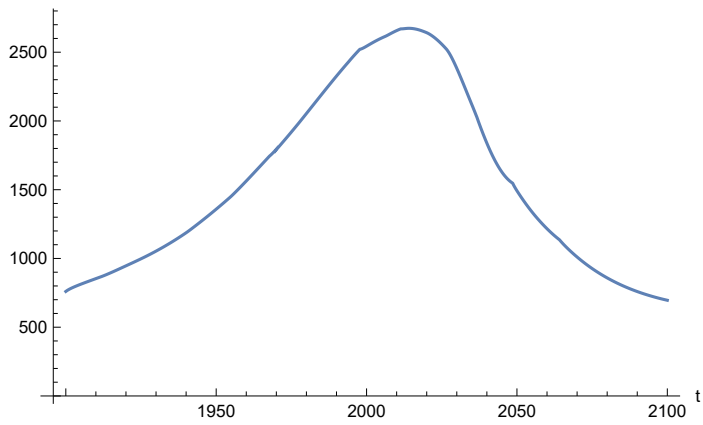
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.03363 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

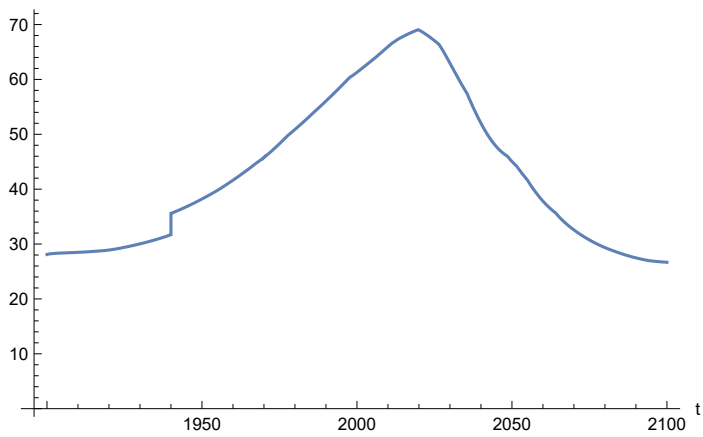
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

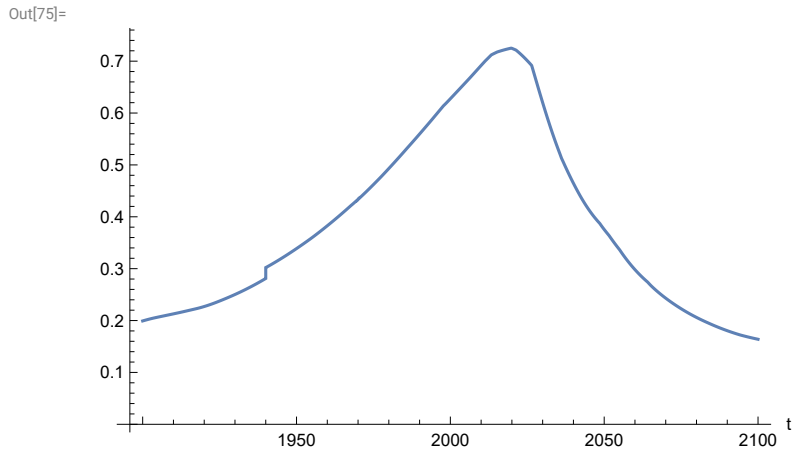
Out[73]=



In[74]:=

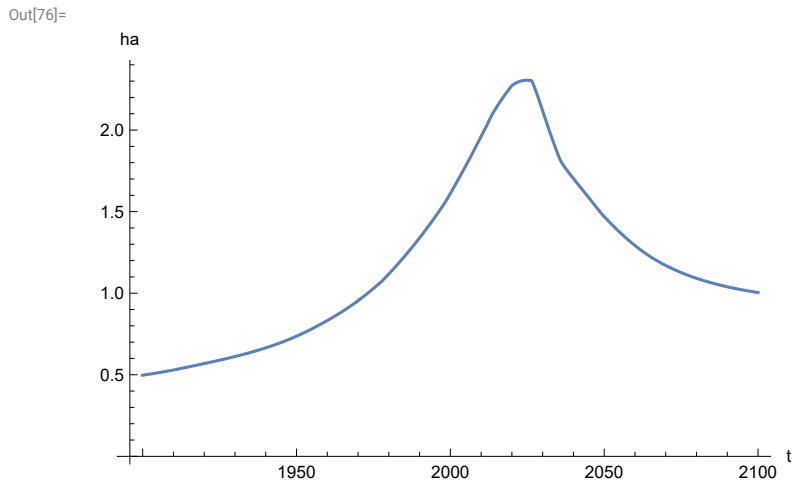
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



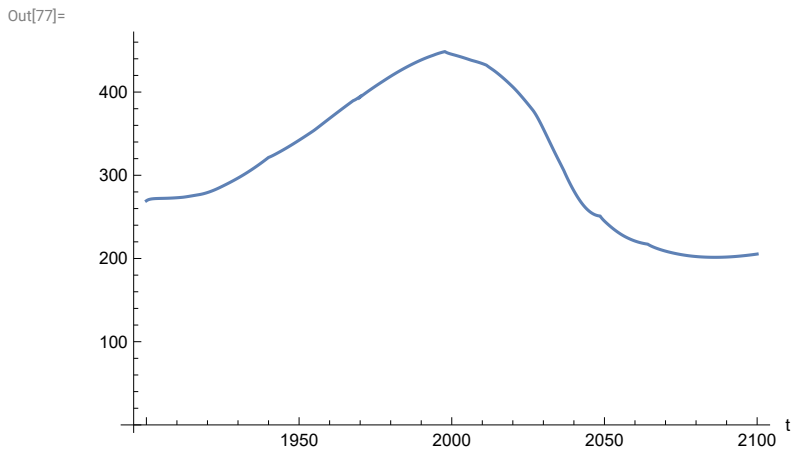
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



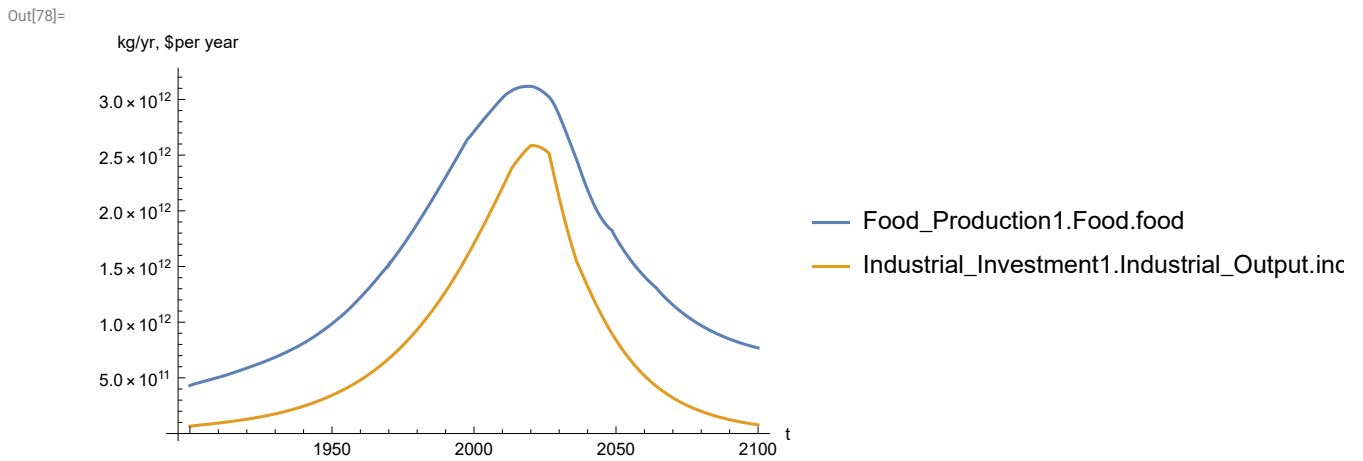
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

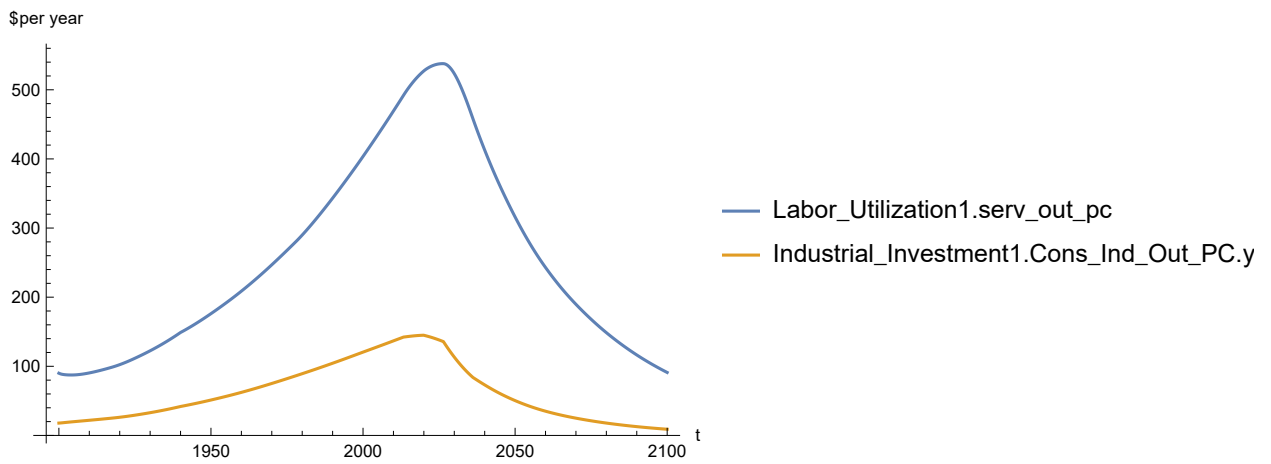
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

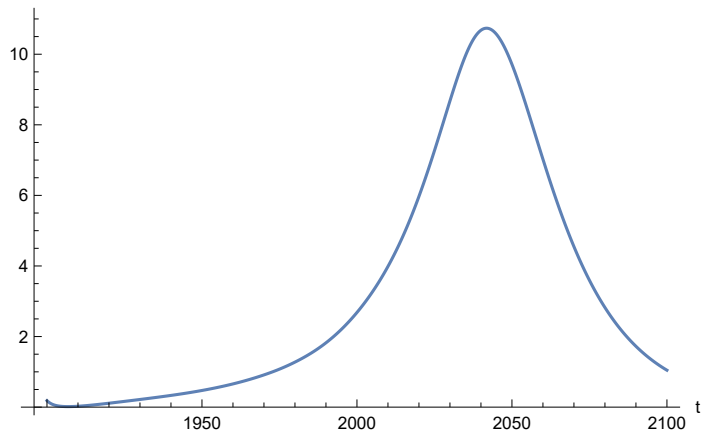
Maximum is 537.818

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

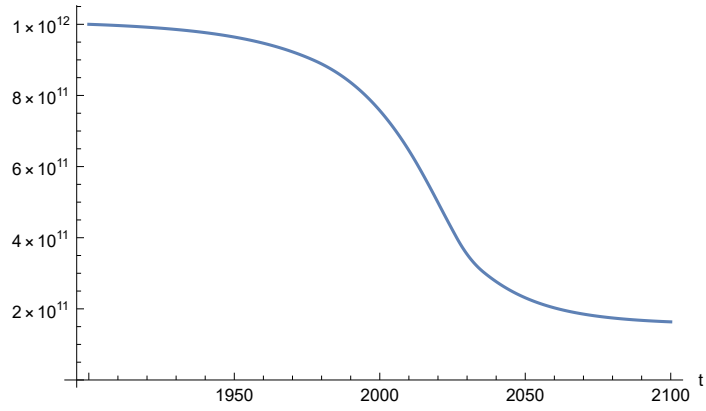
Maximum is 10.737

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

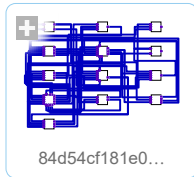
Out[83]=



APPENDIX 11. Baseline Scenario 1, Experiment 11. LE = LE/1.05, t_policity_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

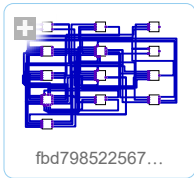
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



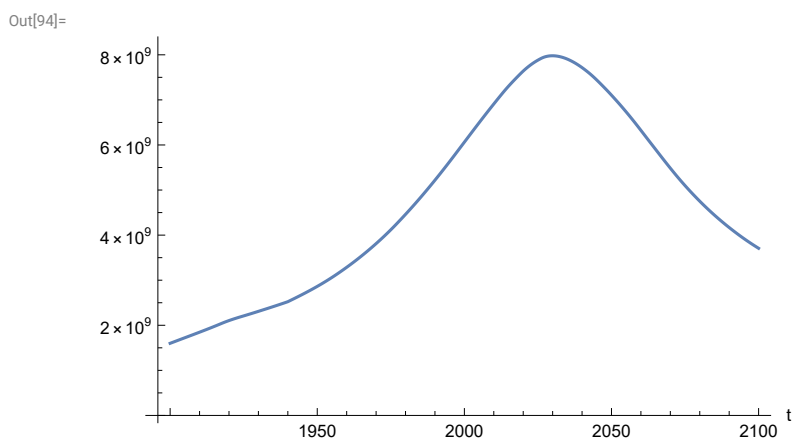
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

```
Out[93]= SystemModelSimulationData [ Model: Wfbd7985225674d8492207848a560a2d4
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

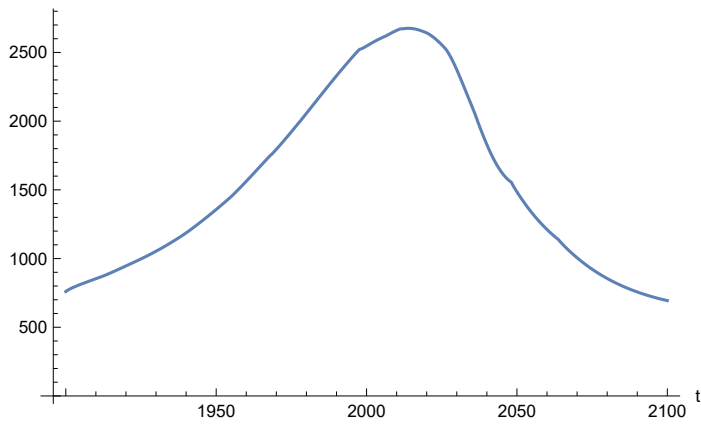
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.9786×10^9

Minimum is 1.6×10^9

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

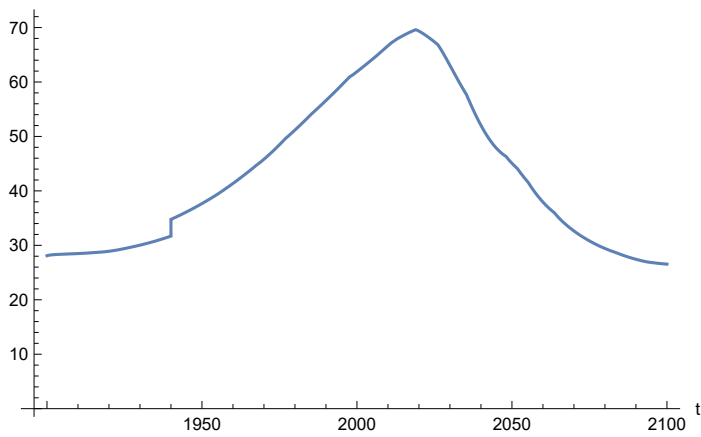
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

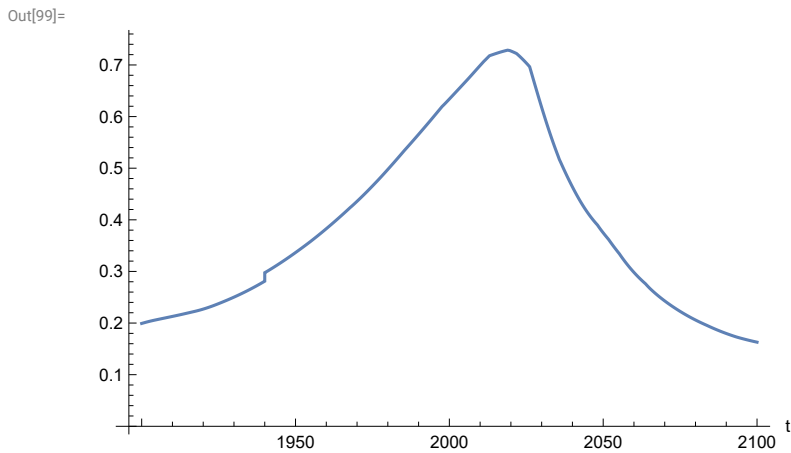
Out[97]=



In[98]=

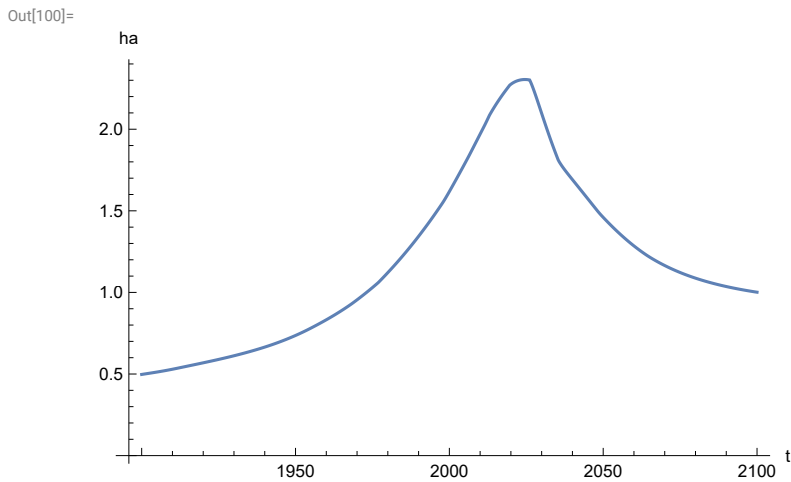
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

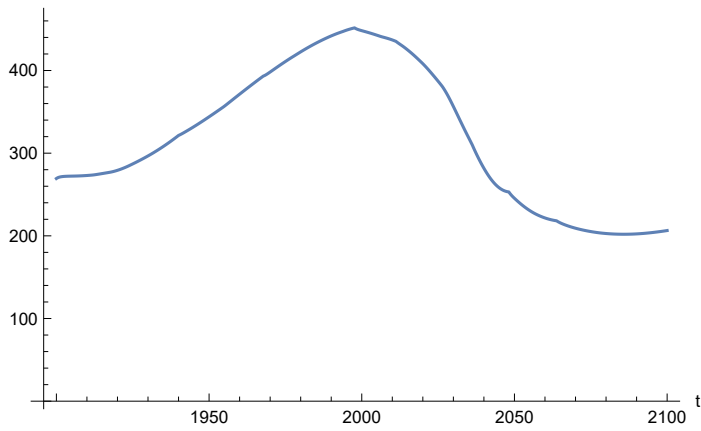


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

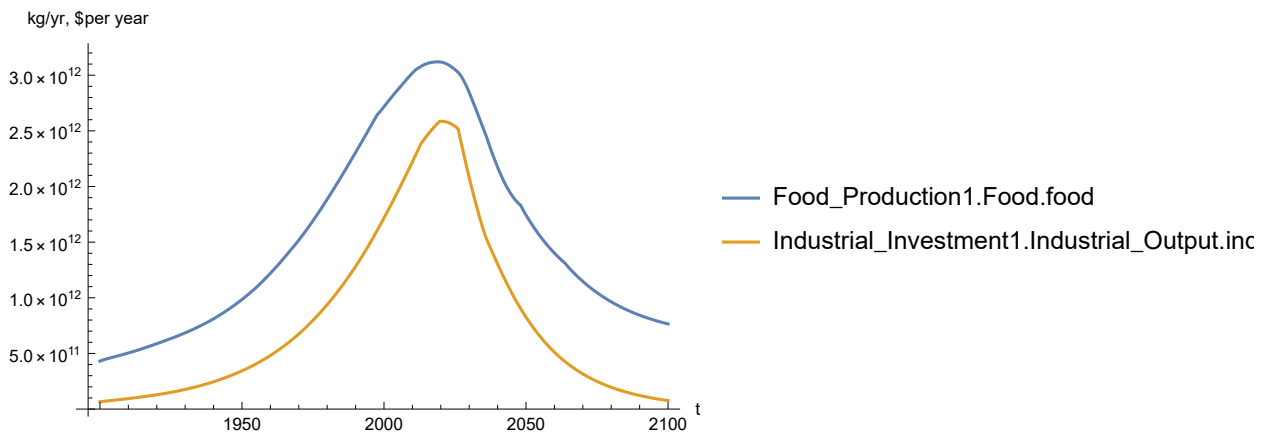


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

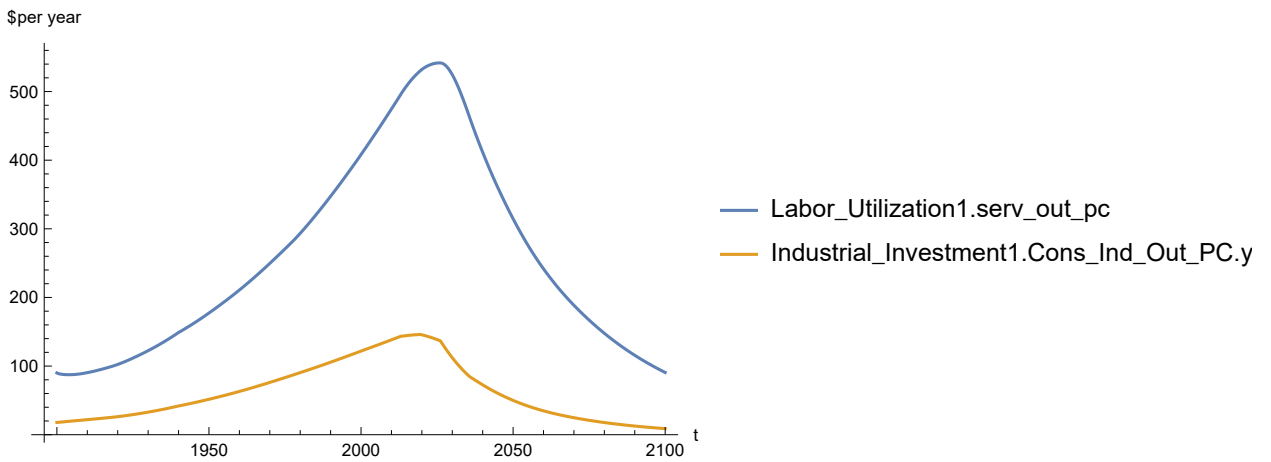


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

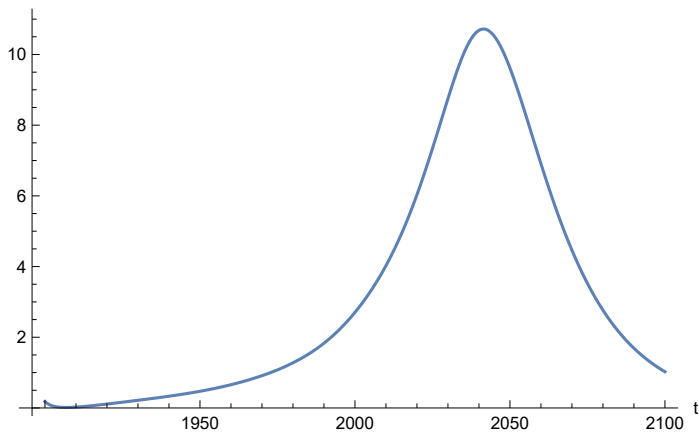
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 541.713
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 10.7196

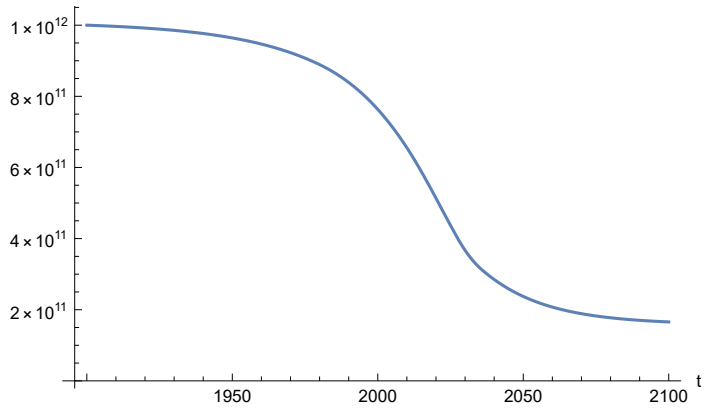
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 12. BENCHMARK SCENARIO 1, Experiment 12. $LE = LE/1.1$, $t_policy_year = 1970$.
Last modified: 22 July 2022/1310 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

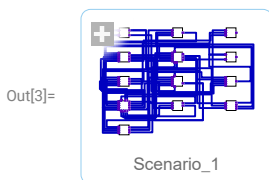
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

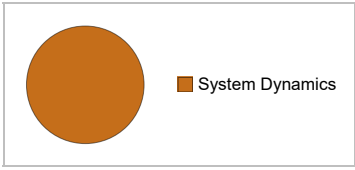
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 1 (“Business as Usual”).

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_1"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_1
	Description	Original WORLD3 model
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

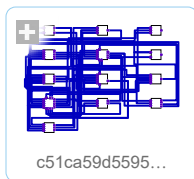
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

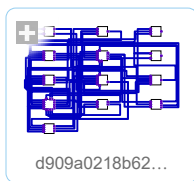
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

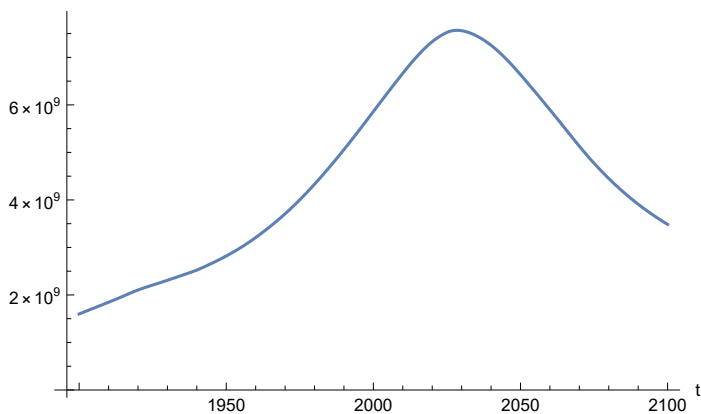
```
Out[21]=
```

```
SystemModelSimulationData [  Model: Wd909a0218b624fa2848802cb18395bb8  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

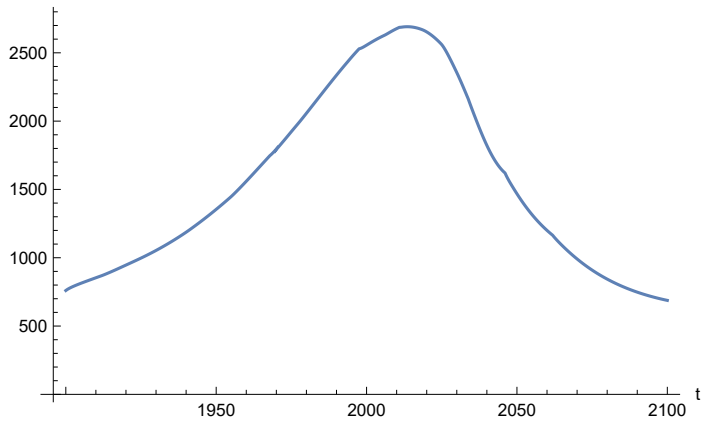
```
Out[22]=
```



Find max and min of population values.

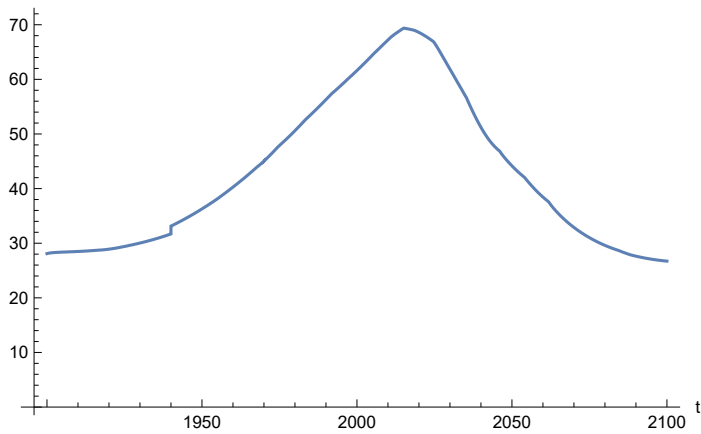
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.56904 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

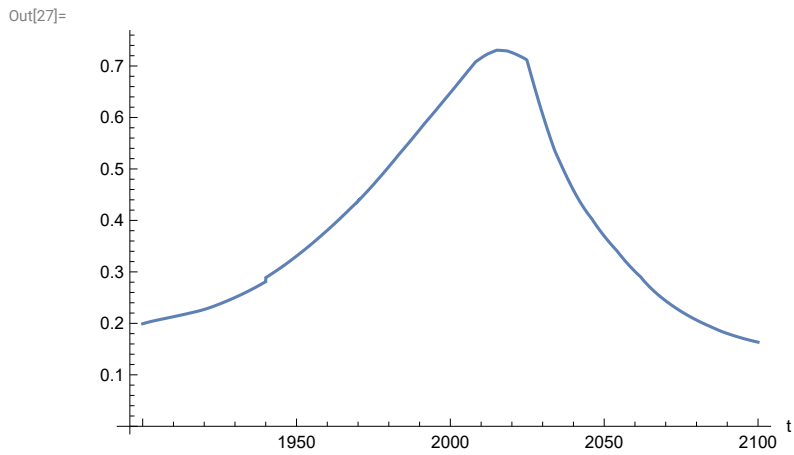
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```



```
In[26]:=
```

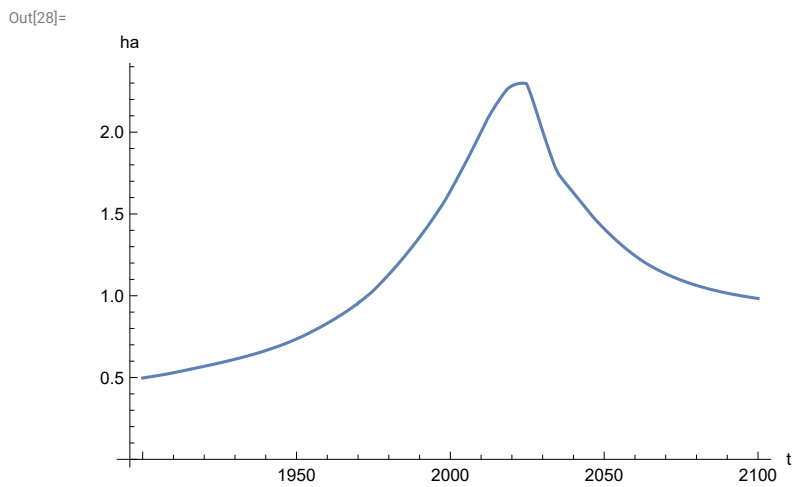
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

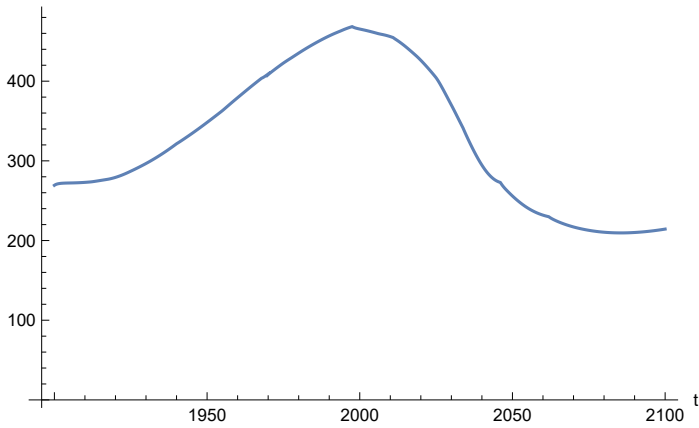
```
In[28]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

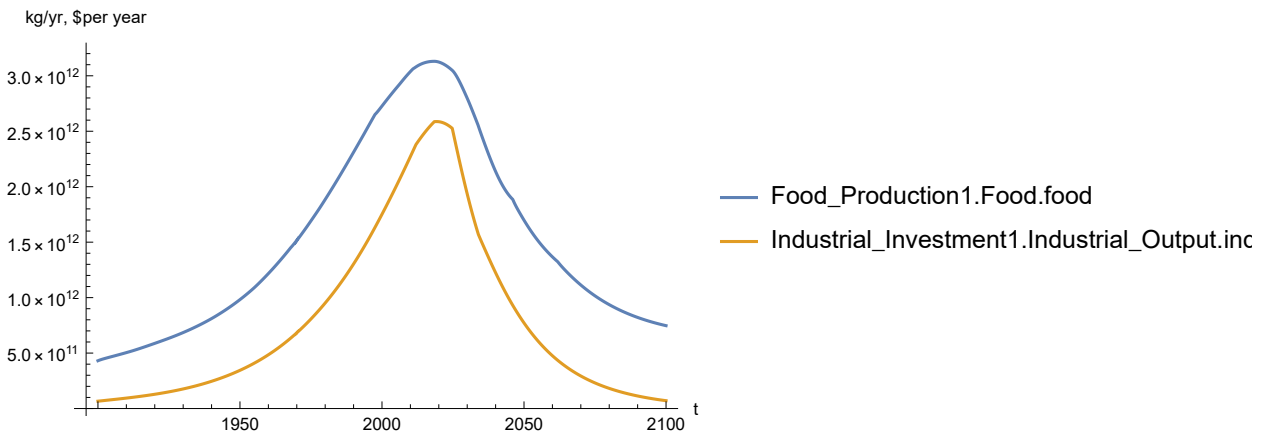
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

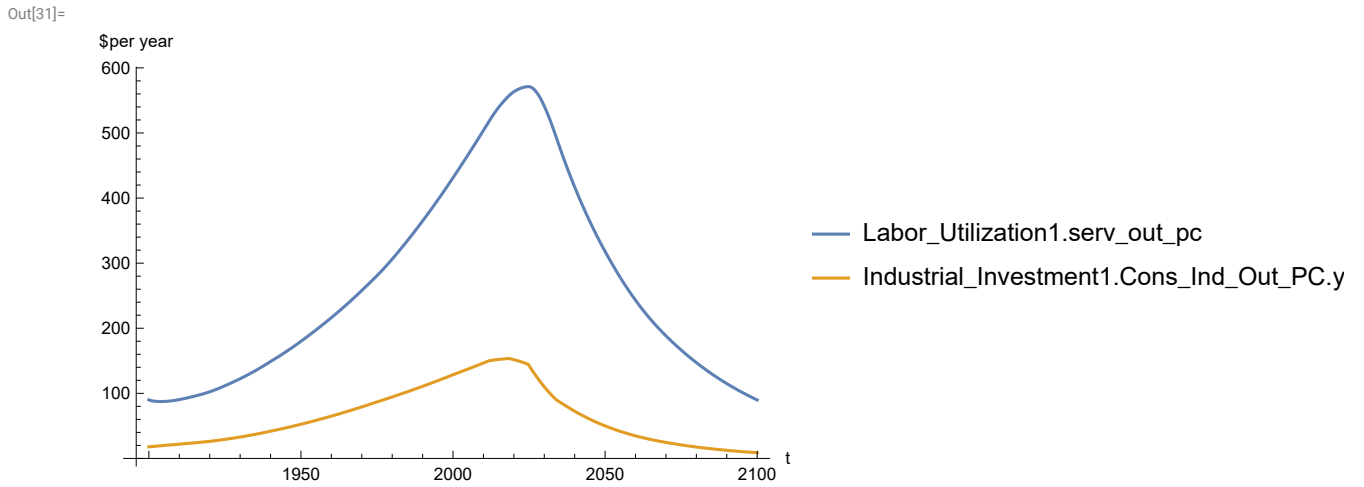
In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

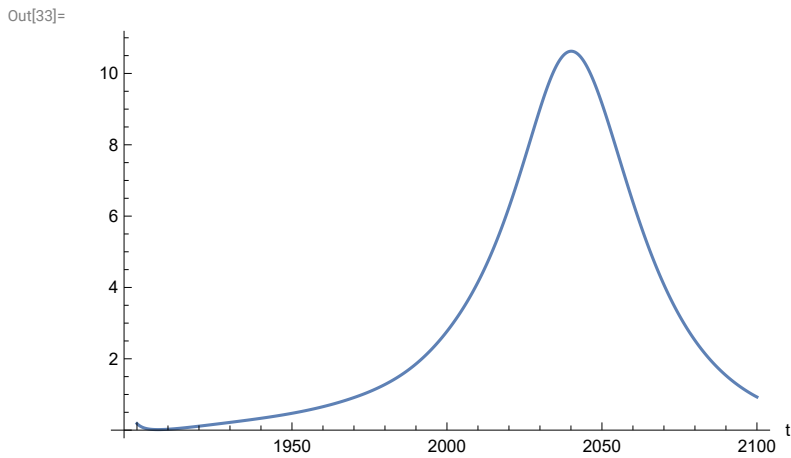


Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 571.174
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



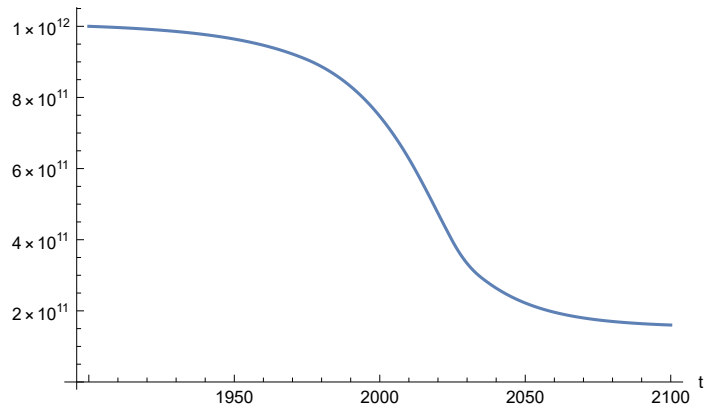
Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.6234
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

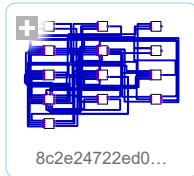


APPENDIX 13. LE/1.1, t_policy_year = 2025. Baseline Scenario 1, Experiment 13.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

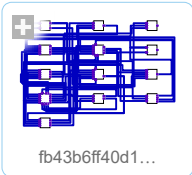
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}

Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```

Out[44]= 

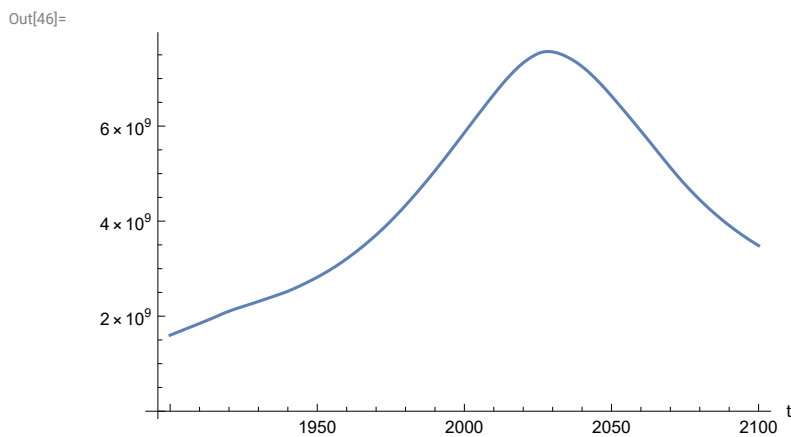
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: Wfb43b6ff40d14911899f4714a140b6f1
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

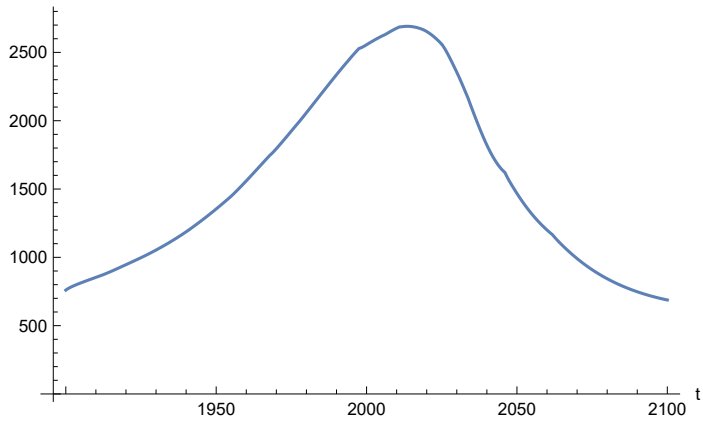
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.56895×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

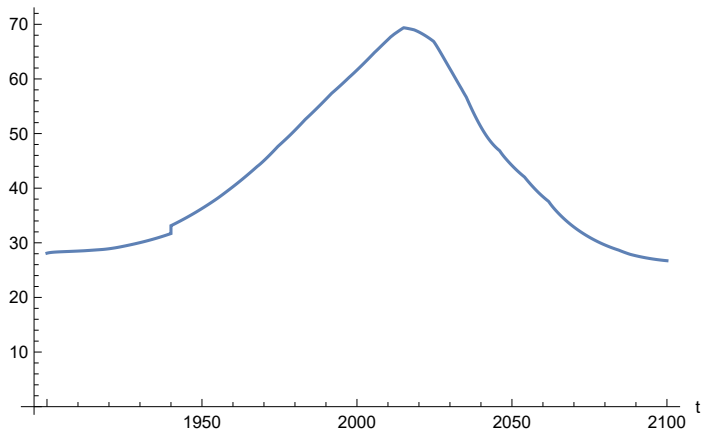
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

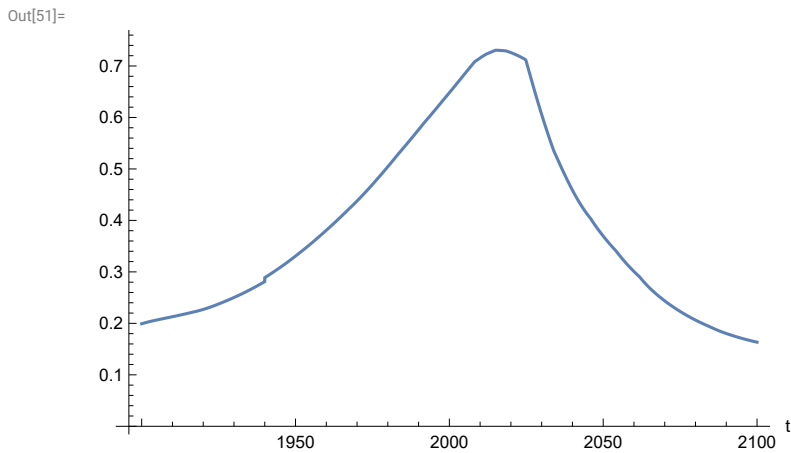
Out[49]=



In[50]:=

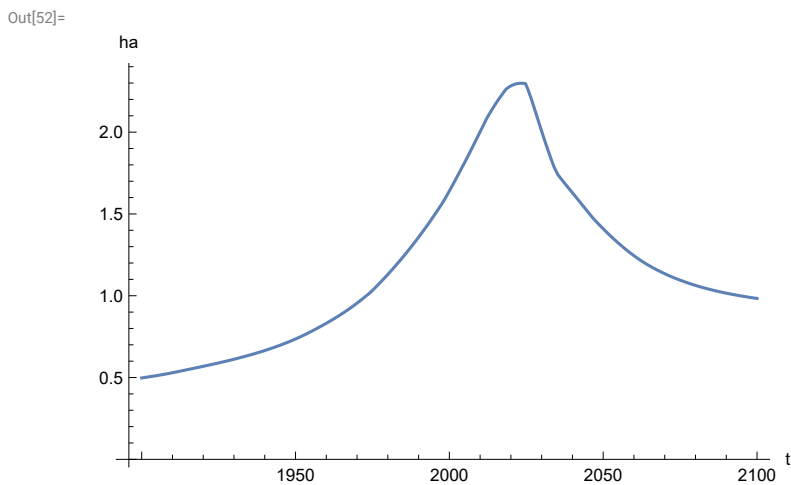
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

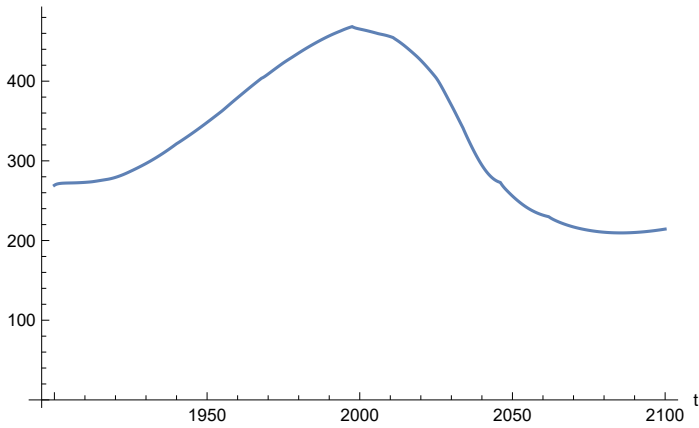
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

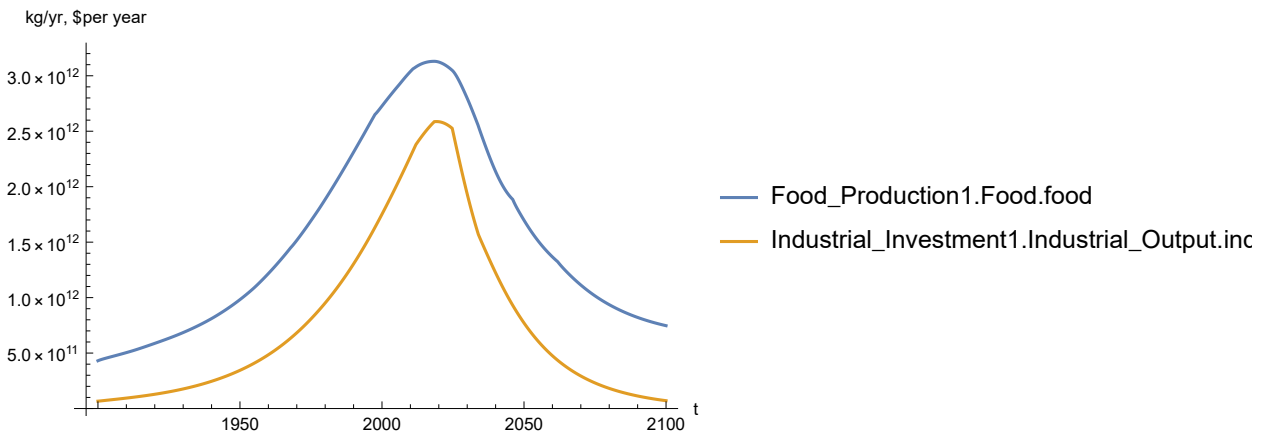
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

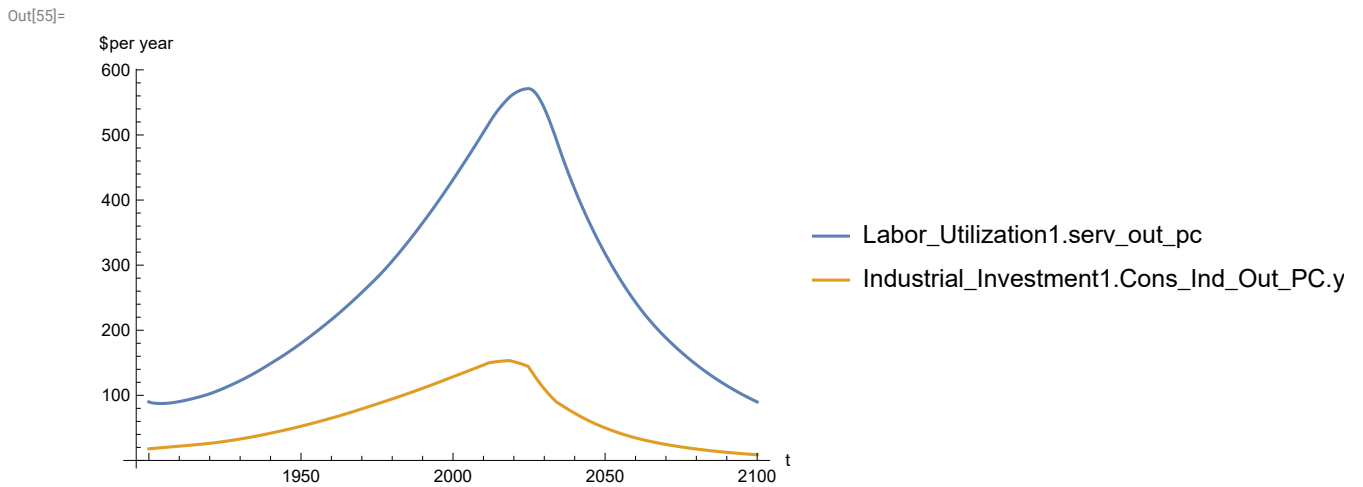
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

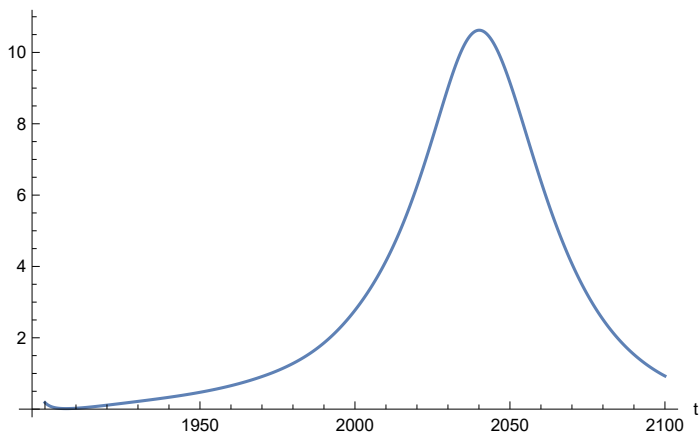


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 571.152
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



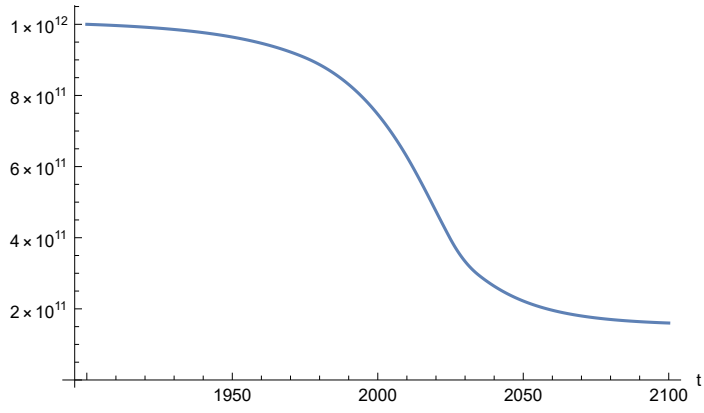
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.6227
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=



APPENDIX 14. BENCHMARK SCENARIO 2, Experiment 14. $t_{policy_year} = 4000$.

Last modified: 22 July 2022/1410 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

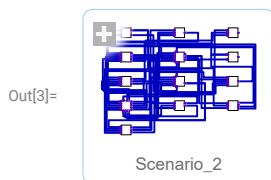
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

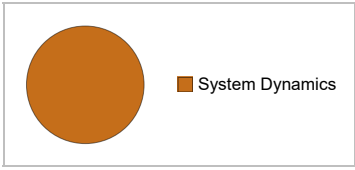
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Here are some high-level properties of unmodified Benchmark Scenario 2.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_2"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_2
	Description	More abundant non-recoverable natural resources
	Simulation Interval	True
	Policy Year	0
	Control Variable	106
	Base Case	True
Out[4]=	Simulation Start	265
	Simulation End	265
	Description	

Show the default value of `t_policy_year`.

```
In[5]:= SystemModel[mysim][{"ParameterValues", "t_policy_year"}]
```

```
Out[5]= {t_policy_year → 4000}
```

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

```
In[6]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[7]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[8]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[9]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute Benchmark Simulation 1 and plot various variables

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

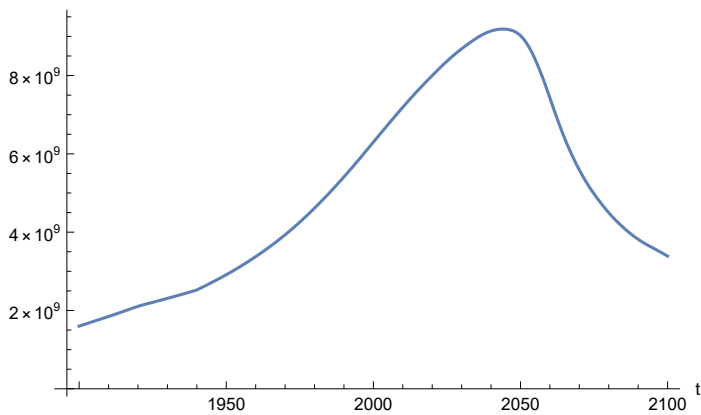
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Scenario_2
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

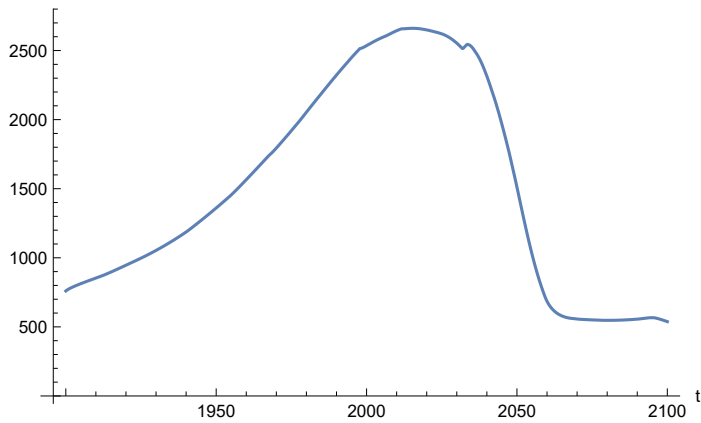
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.18617 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

Out[23]=



Find max and min of y values.

In[24]:= **MinAndMax**[basesim[{"Food_Production1.Land_Yield.y"}]]

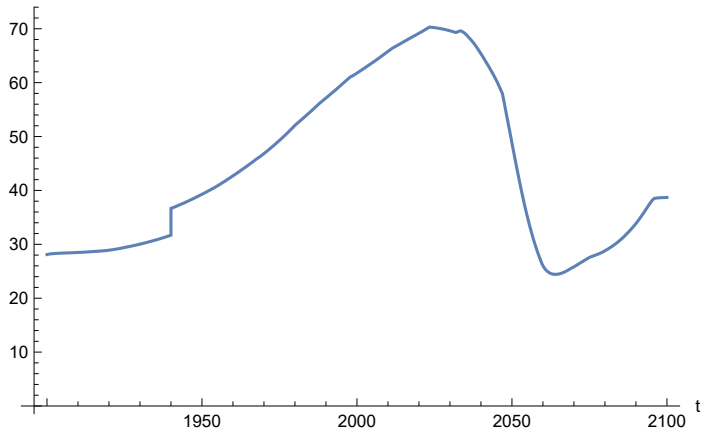
Maximum is 2660.86

Minimum is 537.946

Plot life expectancy, years.

In[25]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

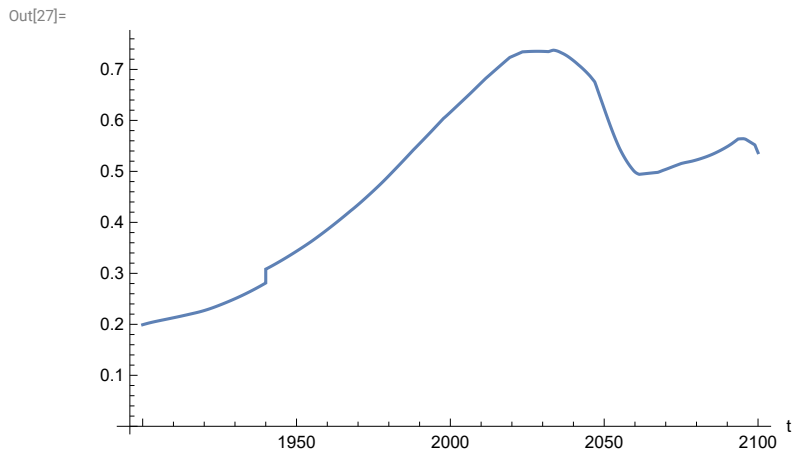
Out[25]=



In[26]:=

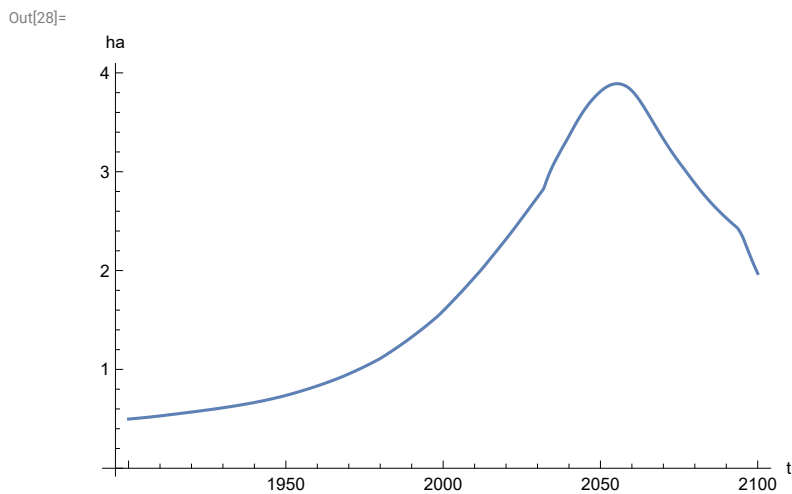
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Find max and min of y values.

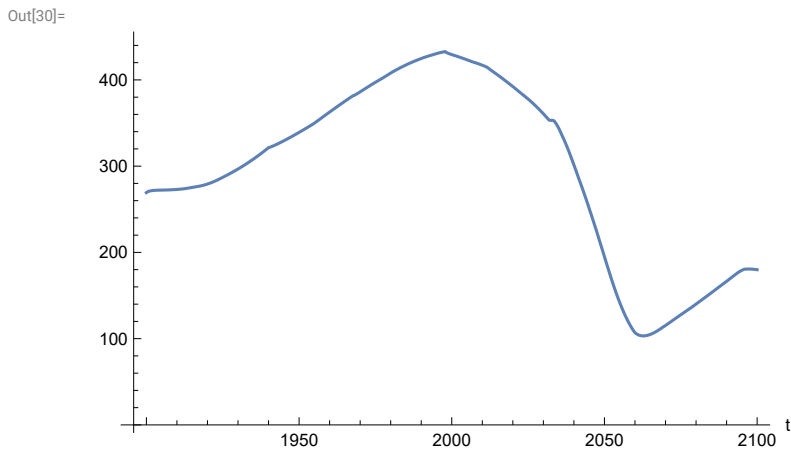
```
In[29]:= MinAndMax[basesim[
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]]
```

Maximum is 3.89061

Minimum is 0.497387

Plot food production per capita (kg/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Find max and min of y values.

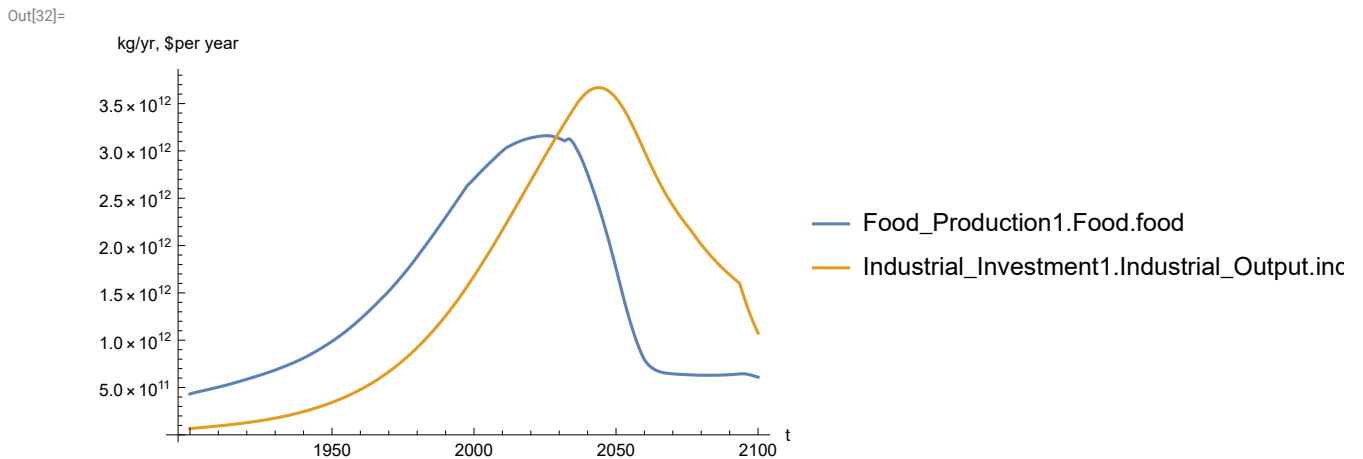
```
In[31]:= MinAndMax[basesim[{"Food_Production1.Food_PC.y"}]]
```

Maximum is 432.786

Minimum is 103.214

Plot total food production (kg/year), and industrial output (dollars/year).

```
In[32]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Find max and min of y values.

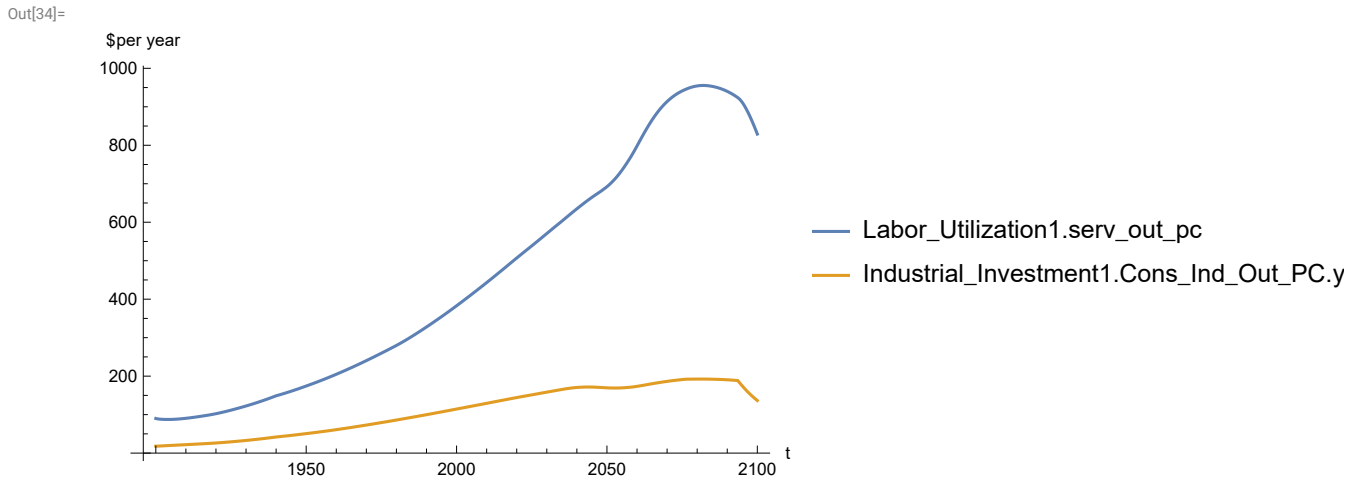
```
In[33]:= MinAndMax[basesim[{"Industrial_Investment1.Industrial_Output.industrial_output"}]]
```

Maximum is 3.66844×10^{12}

Minimum is 6.65×10^{10}

Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[34]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

```
In[35]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 955.429

Minimum is 87.4451

Find max and min of y values.

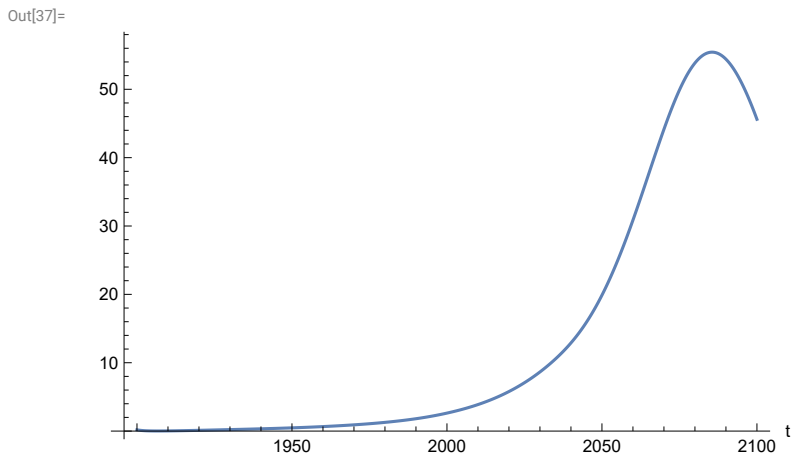
```
In[36]:= MinAndMax[basesim[{"Industrial_Investment1.Cons_Ind_Out_PC.y"}]]
```

Maximum is 192.383

Minimum is 17.8719

Plot persistent pollution index.

```
In[37]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[38]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

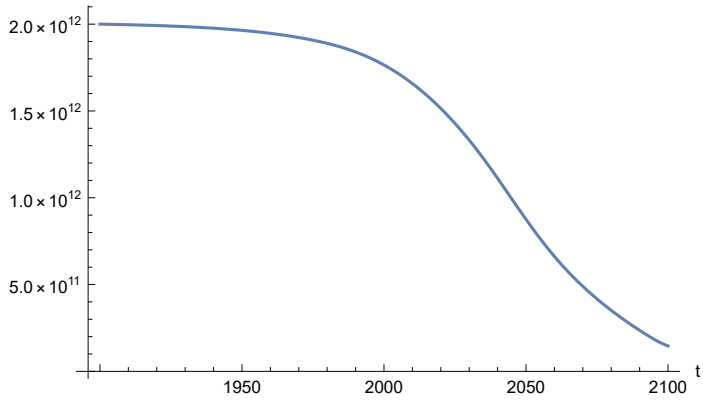
Maximum is 55.4312

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[39]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[39]=

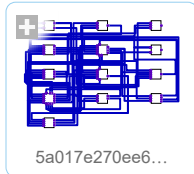


APPENDIX 15. $t_policy_year = 1970$, Benchmark Scenario 2, Experiment 15

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.

```
In[40]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[40]=
```



```
In[41]:= testsim1970 = SystemModelSimulate[newmysim1970]
```

```
Out[41]=
```

```
SystemModelSimulationData [  Model: W5a017e270ee64b55ba6aed9622371eea  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of t_policy_year .

```
In[42]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
```

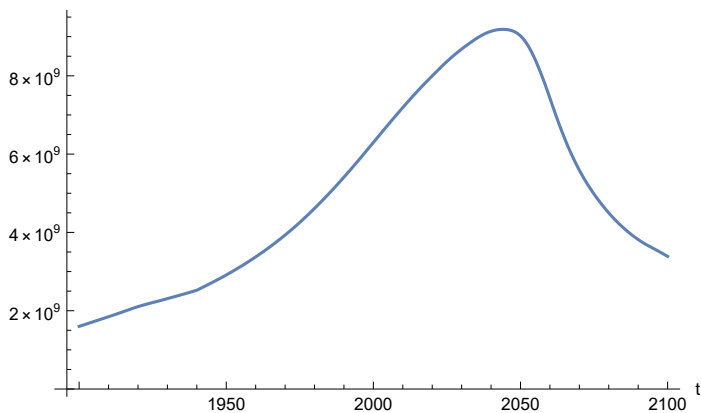
```
Out[42]=
```

```
{t_policy_year → 1970}
```

Plot the world population, people.

```
In[43]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
```

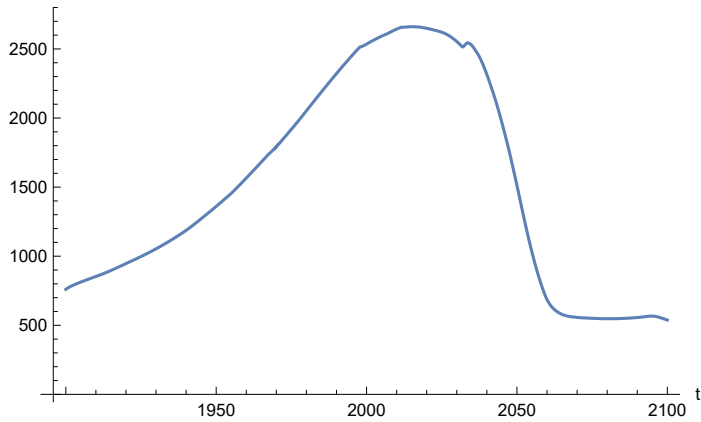
```
Out[43]=
```



Find max and min of y values.

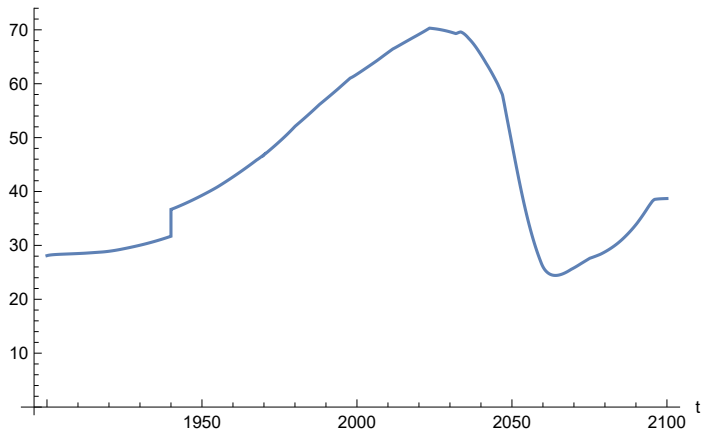
```
In[44]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.18632 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[45]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
Out[45]=
```



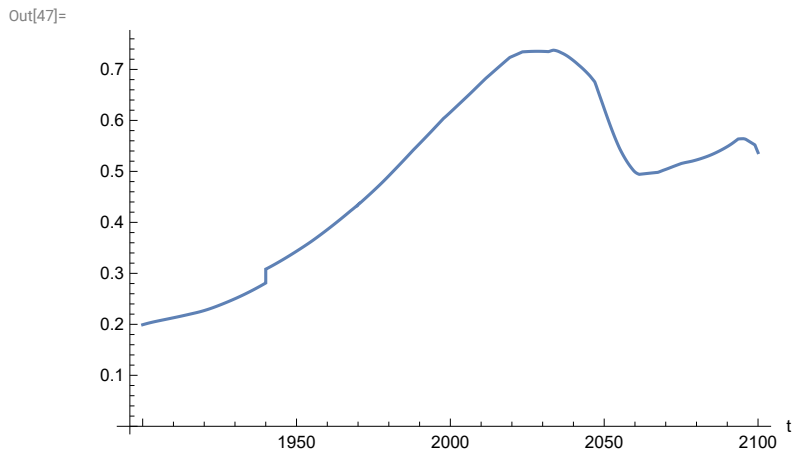
Plot life expectancy, in years.

```
In[46]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[46]=
```



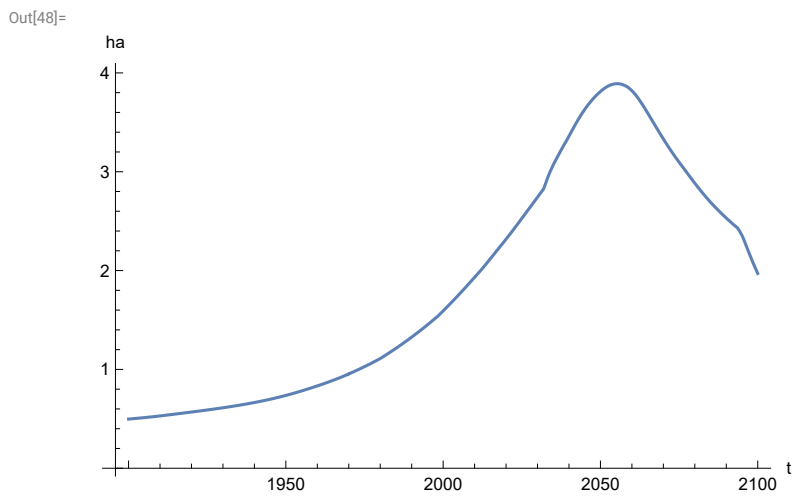
Plot the human welfare index.

```
In[47]:= SystemModelPlot[testsim1970,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



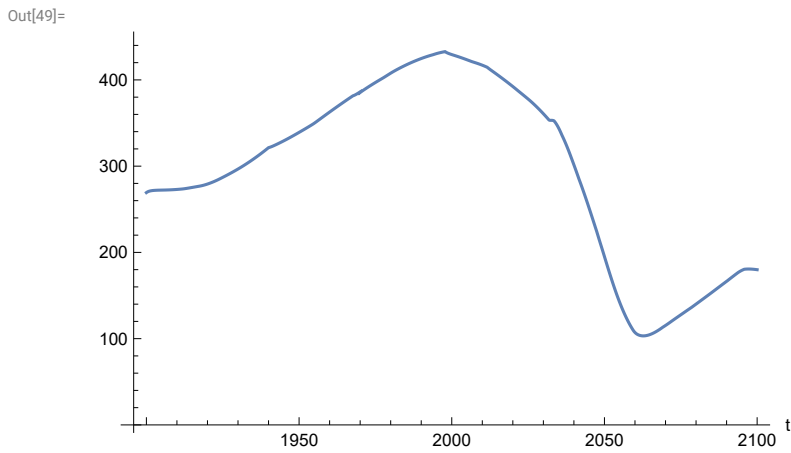
Plot the human ecological footprint, in hectares.

```
In[48]:= SystemModelPlot[testsim1970,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



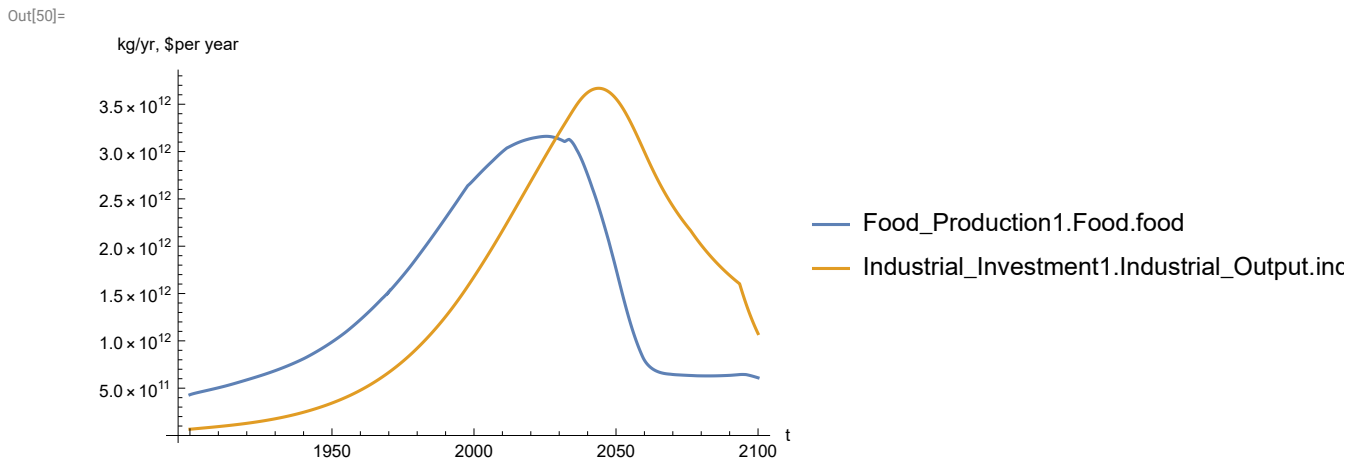
Plot per capita food production, kg/year.

In[49]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]**



Plot total food production (kg/yr) and industrial output (in dollars).

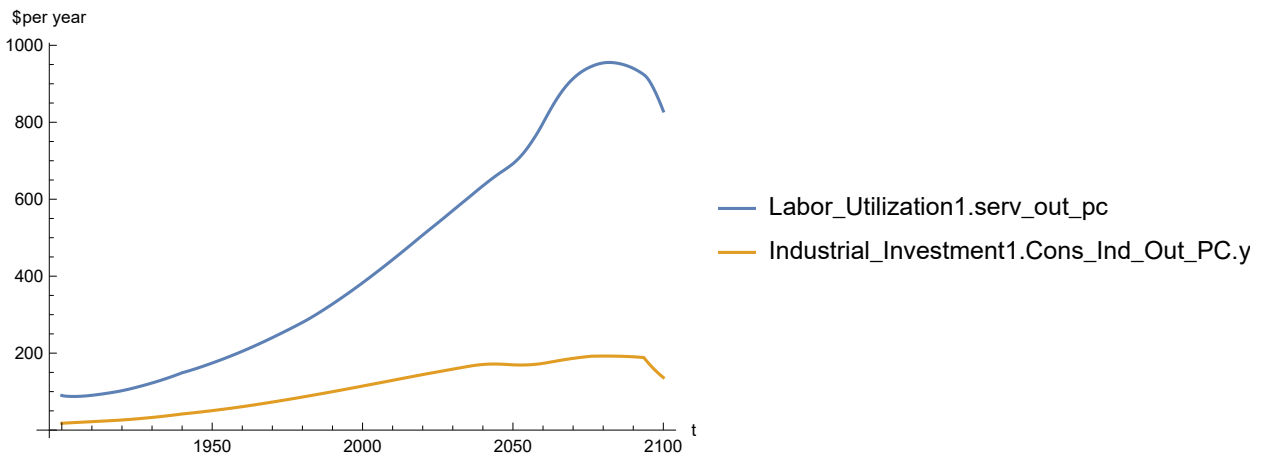
In[50]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[51]:= SystemModelPlot[testsim1970,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[51]=



Find max and min of y values.

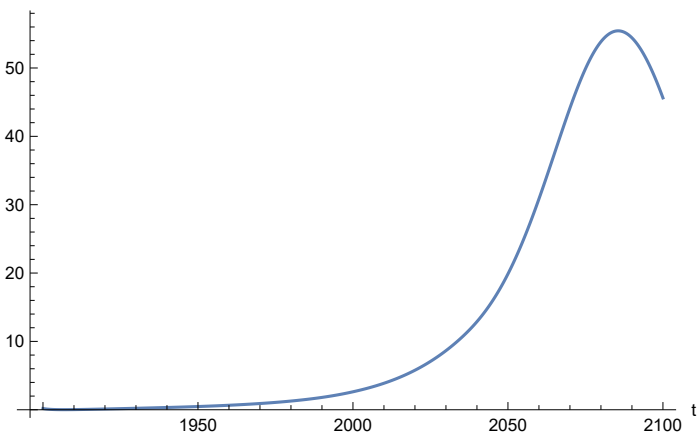
```
In[52]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 955.45
 Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[53]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[53]=



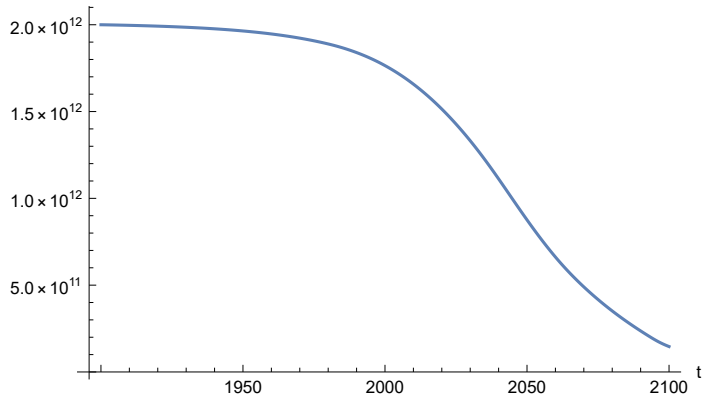
Find max and min of y values.

```
In[54]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 55.4346
 Minimum is 0.0150765

Plot non-renewable resources remaining.

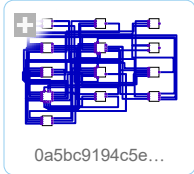
```
In[55]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[55]=
```



APPENDIX 16. Benchmark Scenario 2, t_policy_year set to 2025. Experiment 16.

Change the value of t_policy_year to 2025, and execute the resulting scenario.

```
In[56]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[56]=
```



```
In[57]:= testsim = SystemModelSimulate[newmysim]
Out[57]=
```

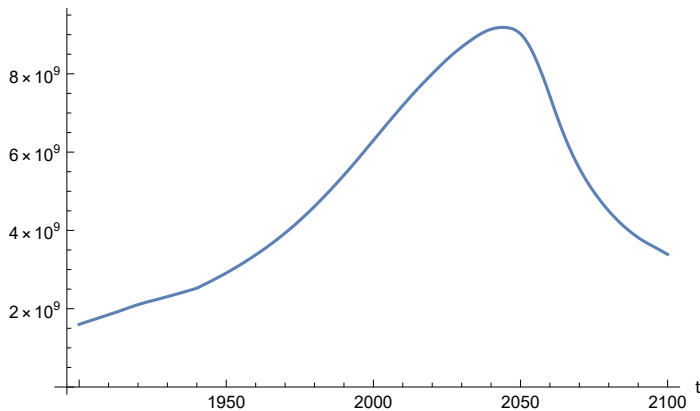
```
SystemModelSimulationData [  Model: W0a5bc9194c5e420c8aaa98df33f234fa  
Time: 1.90 × 103 to 2.10 × 103 ]
```

Show the value of t_policy_year.

```
In[58]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
Out[58]= {t_policy_year → 2025}
```

Plot the world population, people.

```
In[59]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[59]=
```

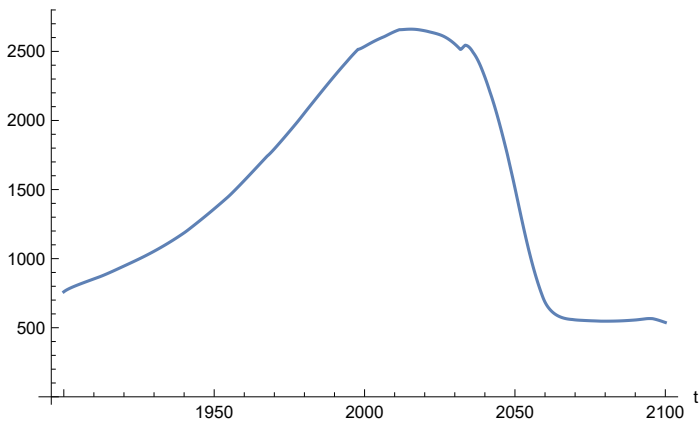


Find max and min of y values.

```
In[60]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.18617 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

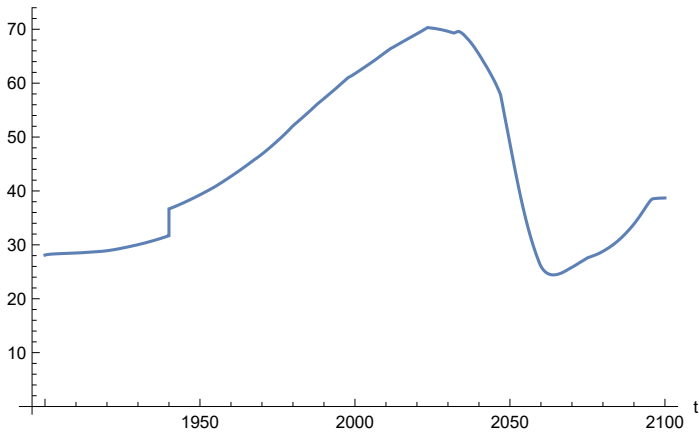
Plot land yield.

```
In[61]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[61]=
```



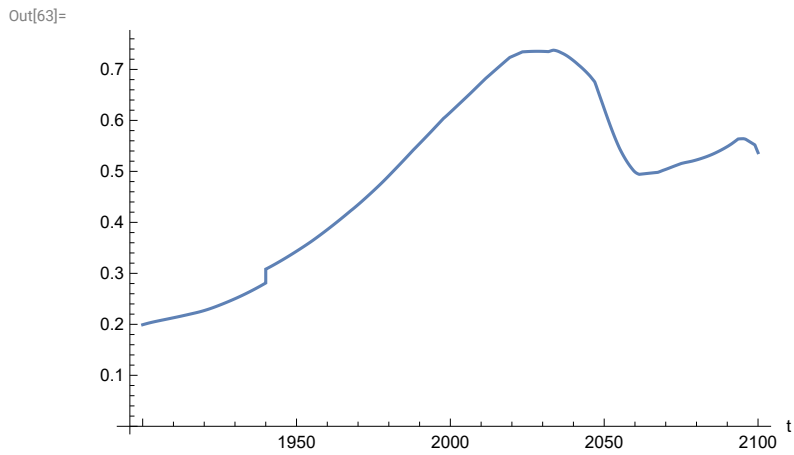
Plot life expectancy, in years.

```
In[62]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[62]=
```



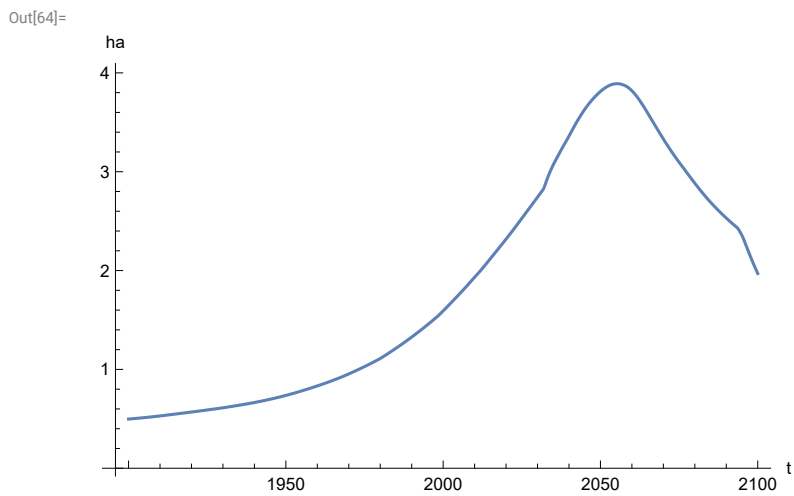
Plot the human welfare index.

```
In[63]:= SystemModelPlot[testsim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



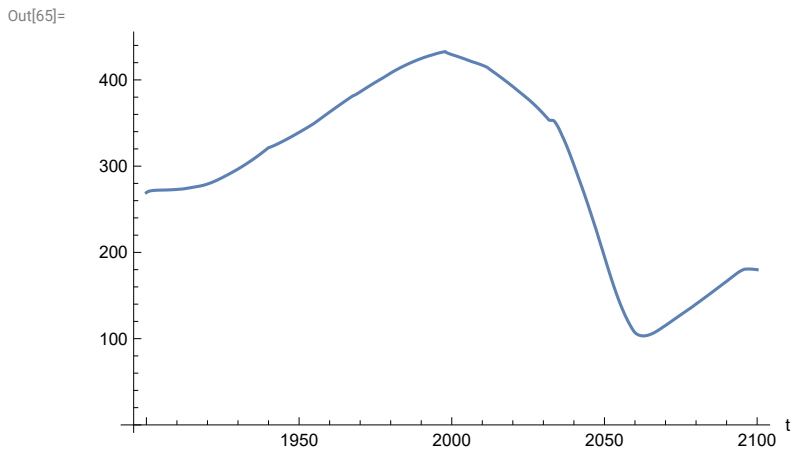
Plot the human ecological footprint, in hectares.

```
In[64]:= SystemModelPlot[testsim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



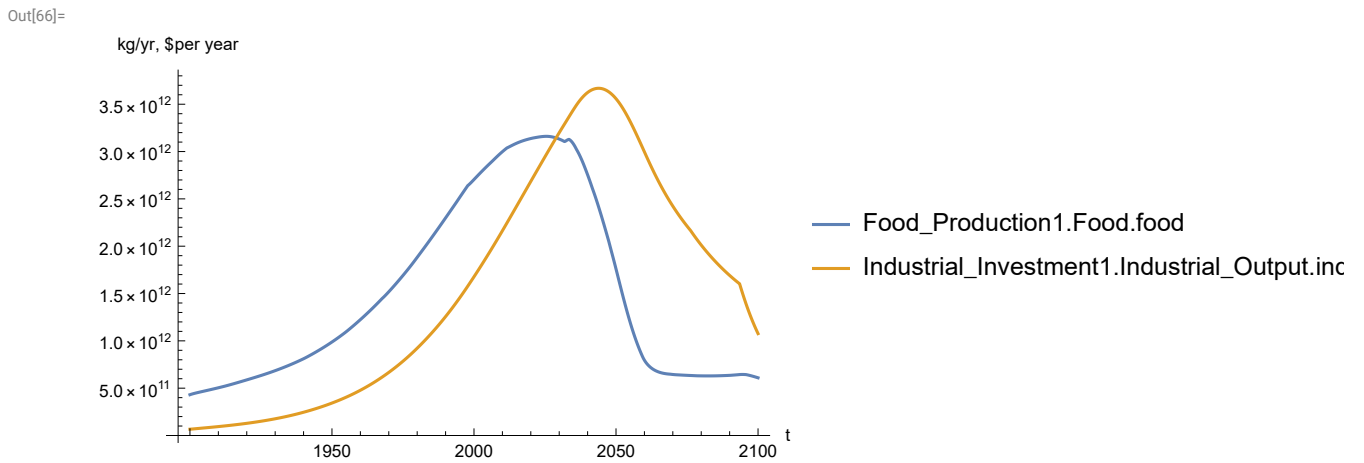
Plot per capita food production, kg/year.

In[65]:= **SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]**



Plot total food production (kg/yr) and industrial output (in dollars).

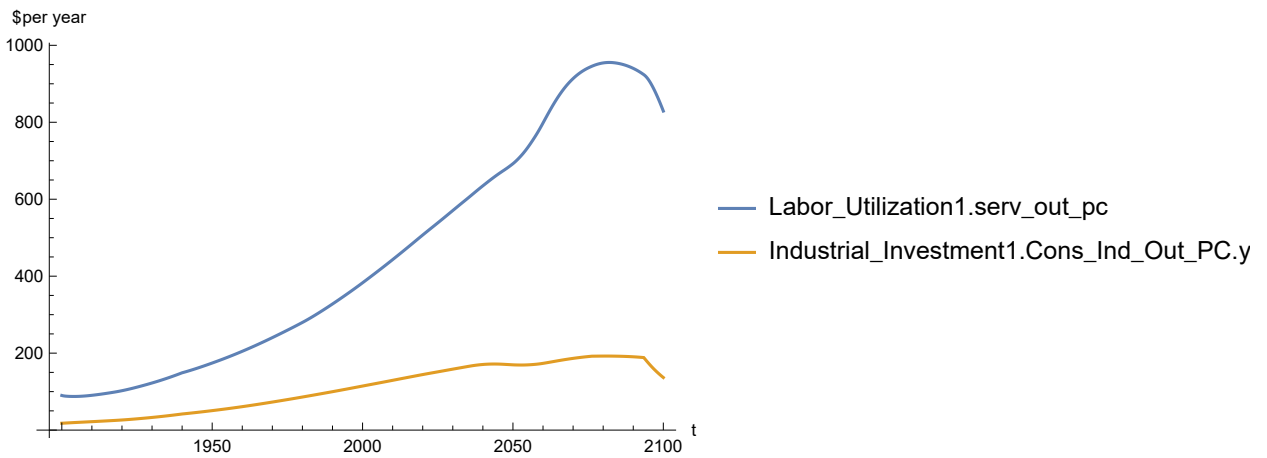
In[66]:= **SystemModelPlot[testsim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**



Plot consolidated industrial output per capita (dollars/year).

```
In[67]:= SystemModelPlot[testsim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[67]=



Find max and min of y values.

```
In[68]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
```

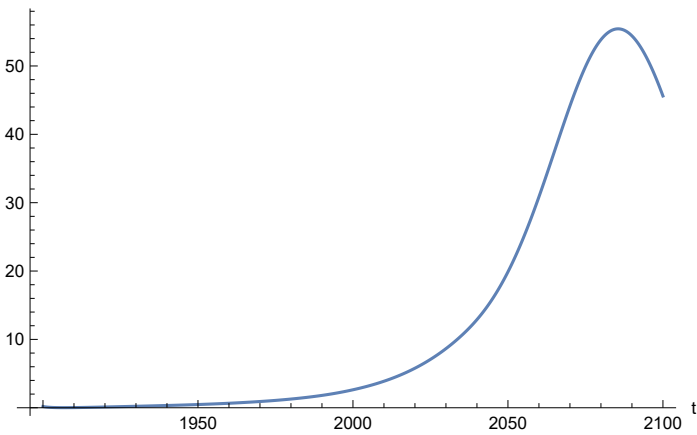
Maximum is 955.428

Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[69]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[69]=



Find max and min of y values.

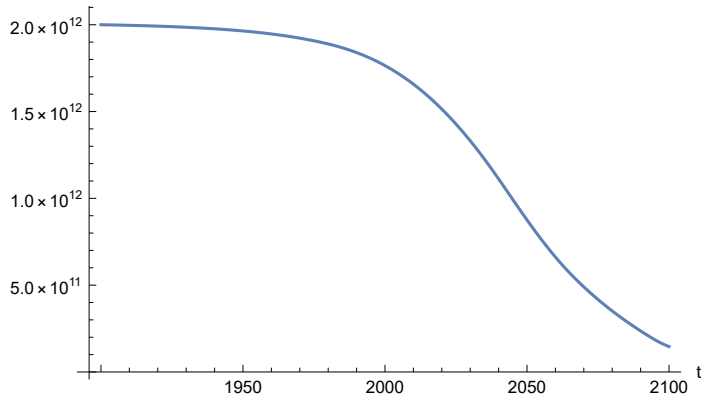
```
In[70]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 55.4311

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[71]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[71]=
```



APPENDIX 17. BENCHMARK SCENARIO 2, Experiment 17. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 23 July 2022/0830 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

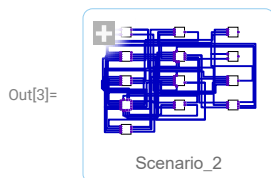
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

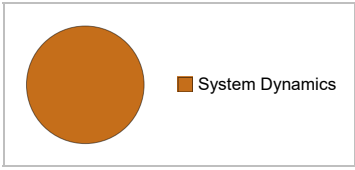
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 2.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_2"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_2
	Description	More abundant non-recoverable natural resources
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	Simulation Start	265
	Simulation End	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

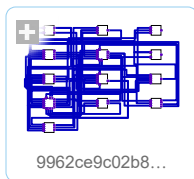
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

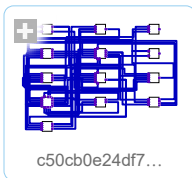
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

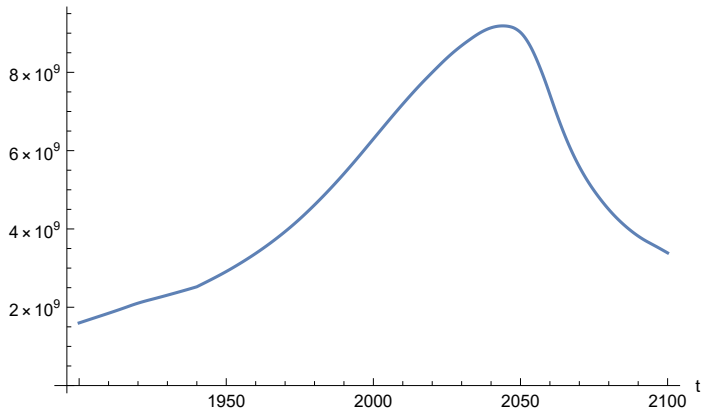
```
Out[21]=
```

```
SystemModelSimulationData [  Model: Wc50cb0e24df74630a0559dddad99df8e  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

In[22]:= **SystemModelPlot**[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]

Out[22]=



Find max and min of population values.

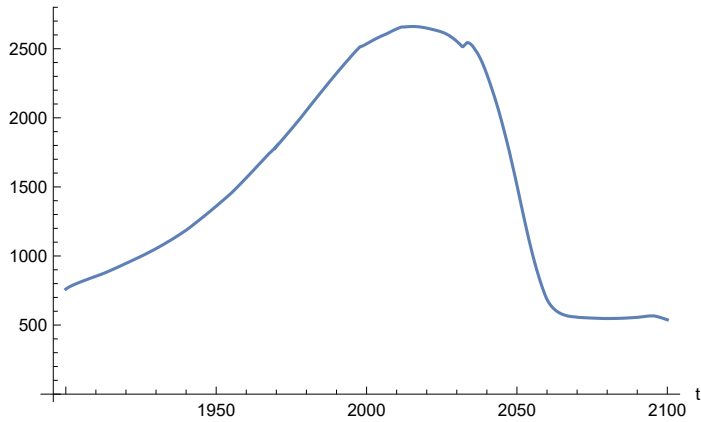
In[23]:= **MinAndMax**[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]

Maximum is 9.18632×10^9

Minimum is 1.6×10^9

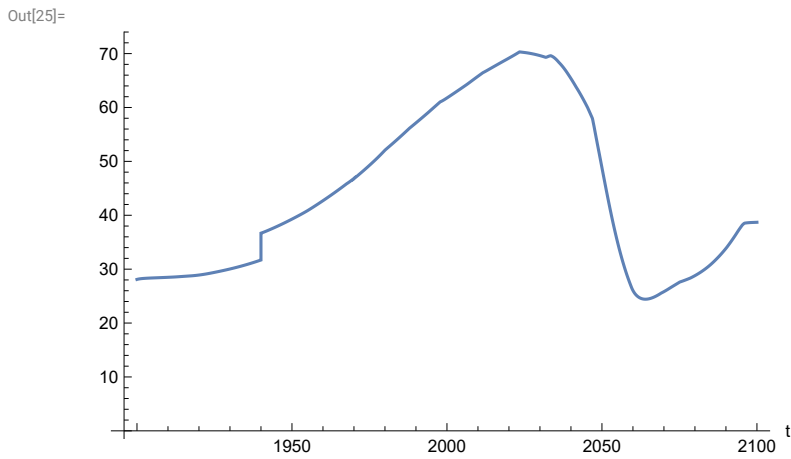
In[24]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

Out[24]=



Plot life expectancy, years.

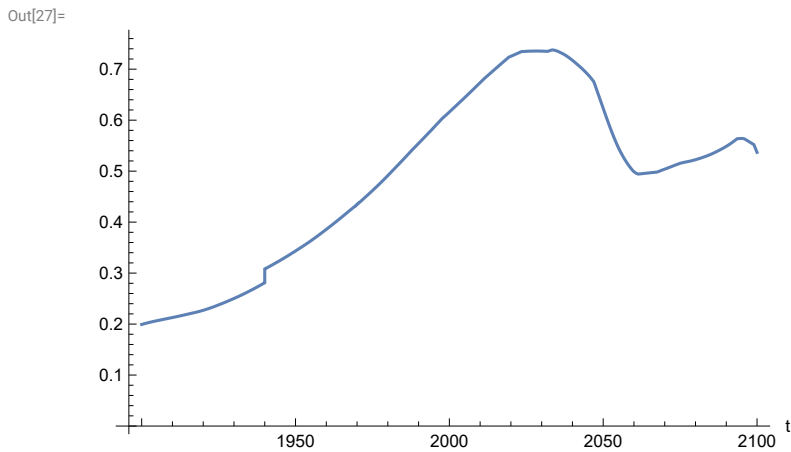
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[26]:=
```

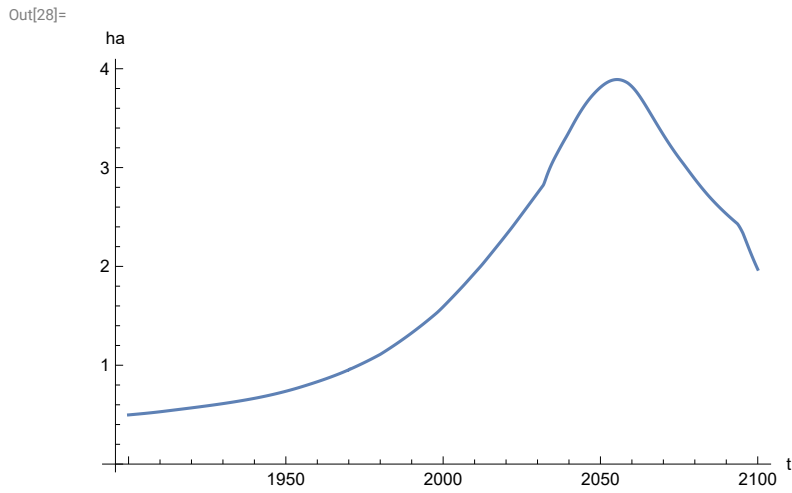
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



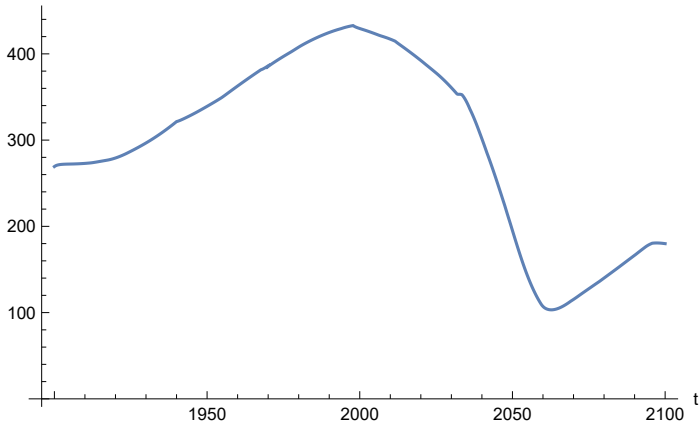
Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



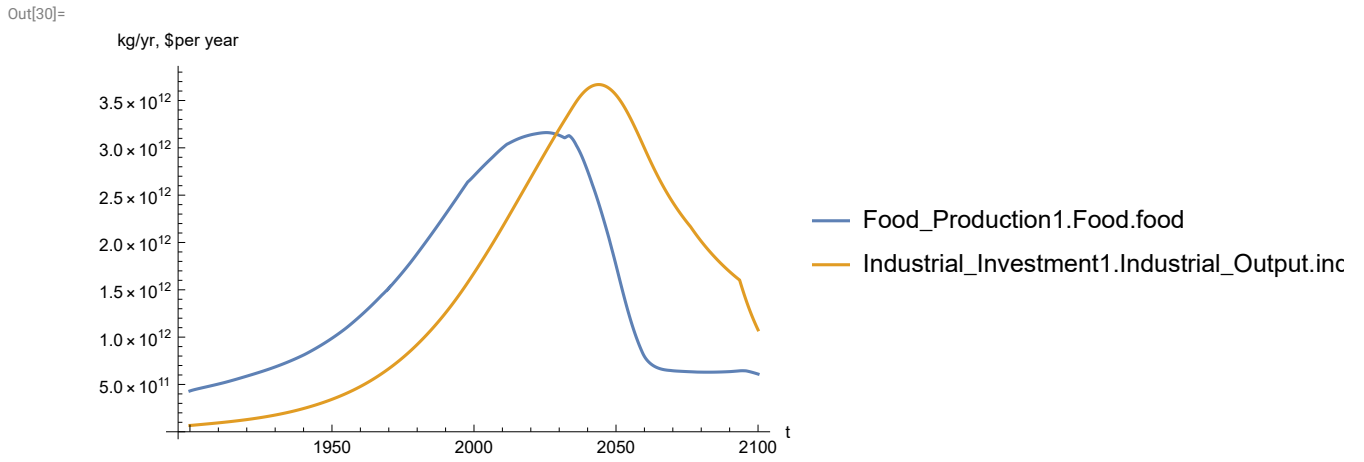
Plot food production per capita (kg/year).

```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
Out[29]=
```



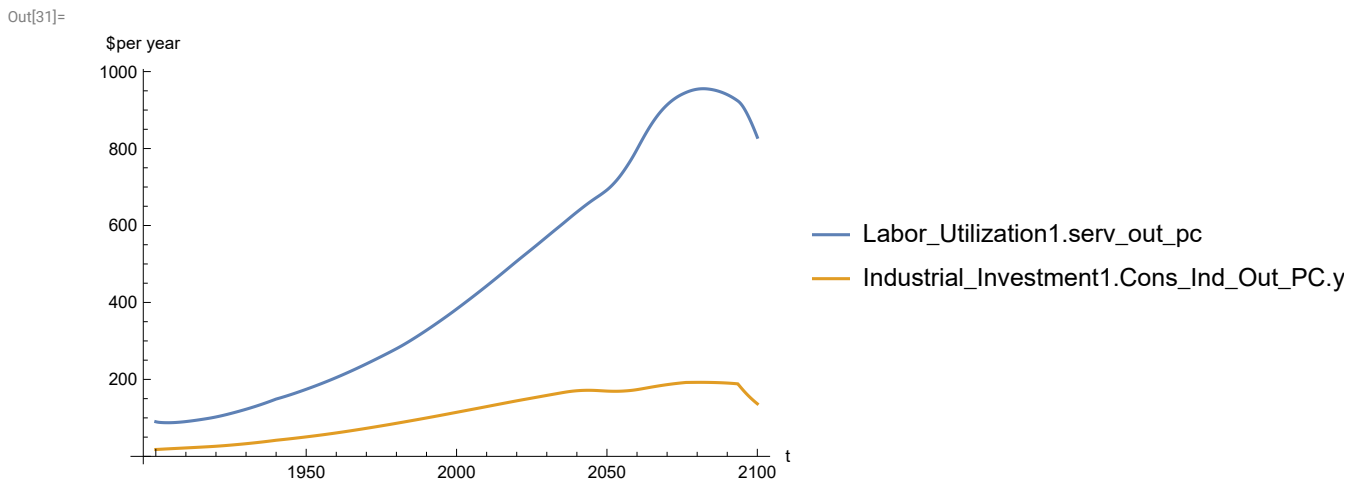
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

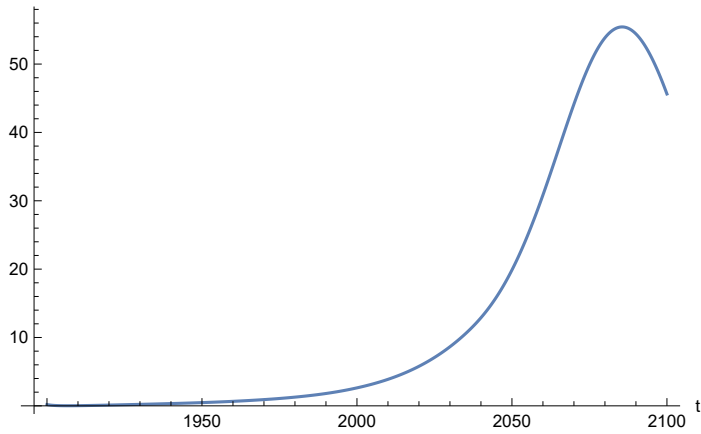
```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 955.45
Minimum is 87.4451

Plot persistent pollution index.

In[33]:= **SystemModelPlot**[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]

Out[33]=



Find max and min of y values.

In[34]:= **MinAndMax**[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]

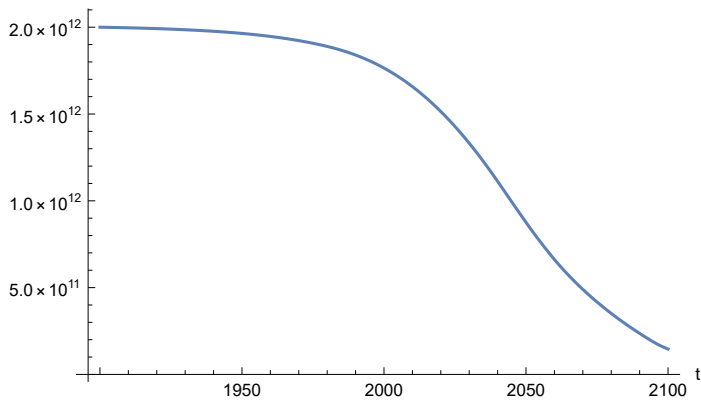
Maximum is 55.4346

Minimum is 0.0150765

Plot non-renewable resources remaining.

In[35]:= **SystemModelPlot**[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]

Out[35]=

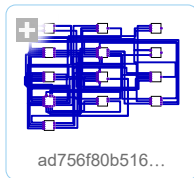


APPENDIX 18. LE/1.001, t_policy_year = 2025. Baseline Scenario 2, Experiment 18.

Set `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals` to LE/1.001. Note: this particular divisor does not change the two-significant-figure default `_Serv_2.y_vals`

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[36]=



Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals`.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

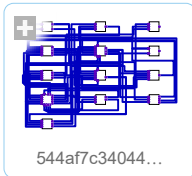
```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

```
Out[44]=
```



Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

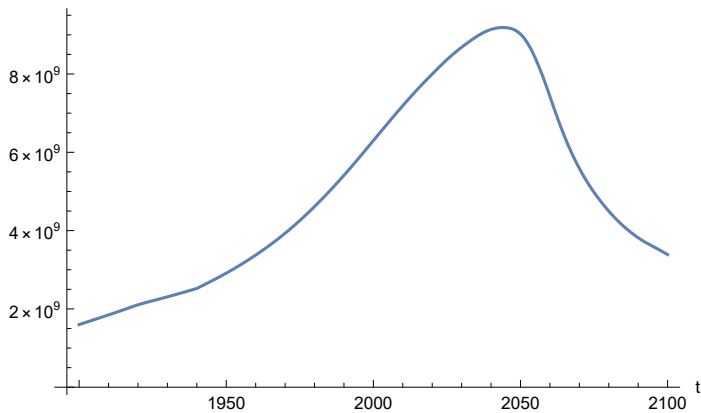
```
Out[45]=
```

```
SystemModelSimulationData [ {  Model: W544af7c340444a3a9b1e4ede38551e5d
  Time: 1.90 × 103 to 2.10 × 103 } ]
```

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[46]=
```



Find max and min of population values.

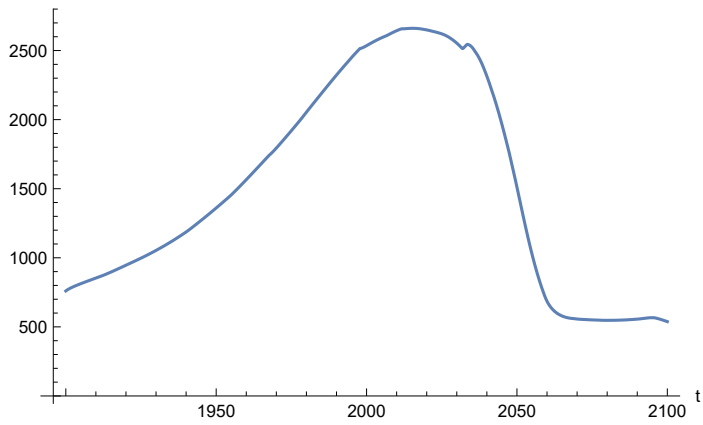
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.18617 × 109
```

```
Minimum is 1.6 × 109
```

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

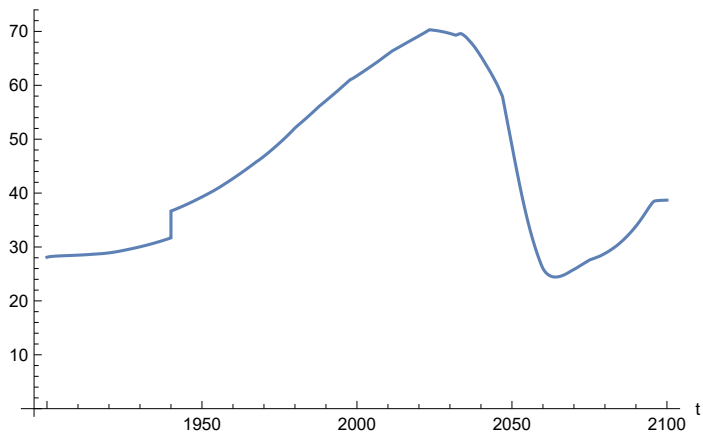
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

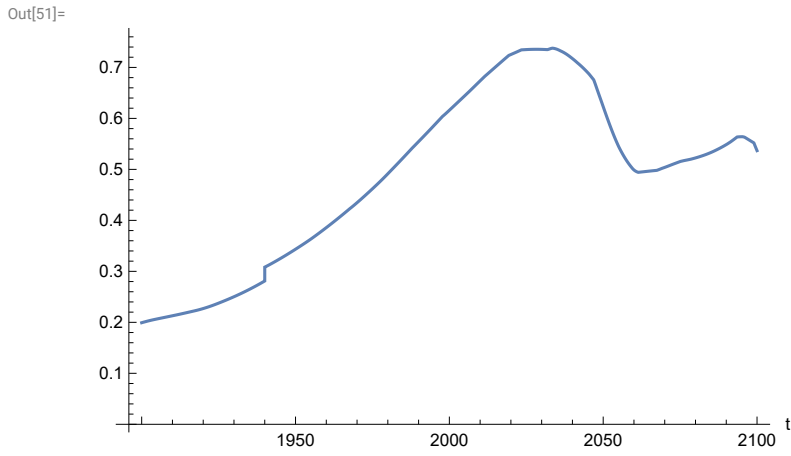
Out[49]=



In[50]:=

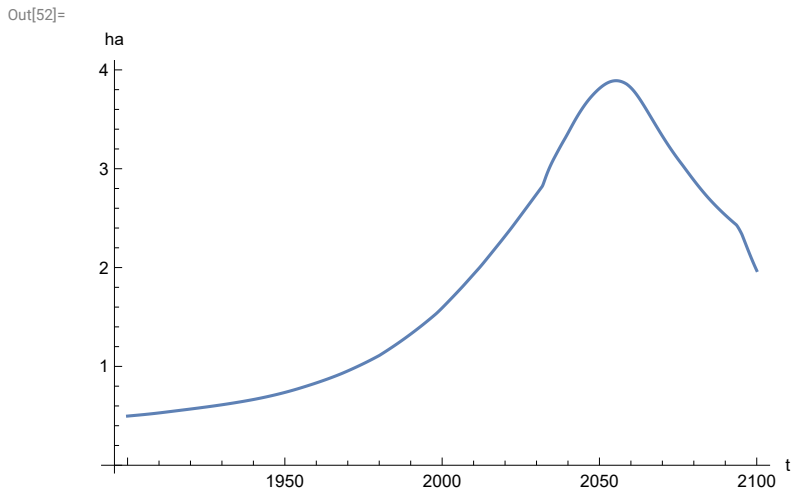
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



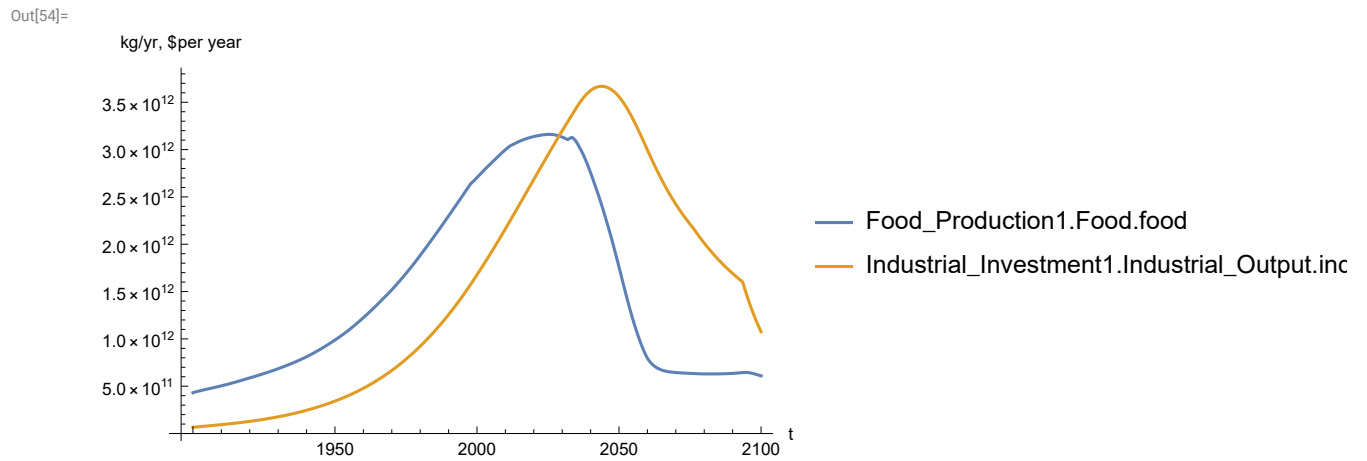
Plot food production per capita (kg/year).

```
In[53]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



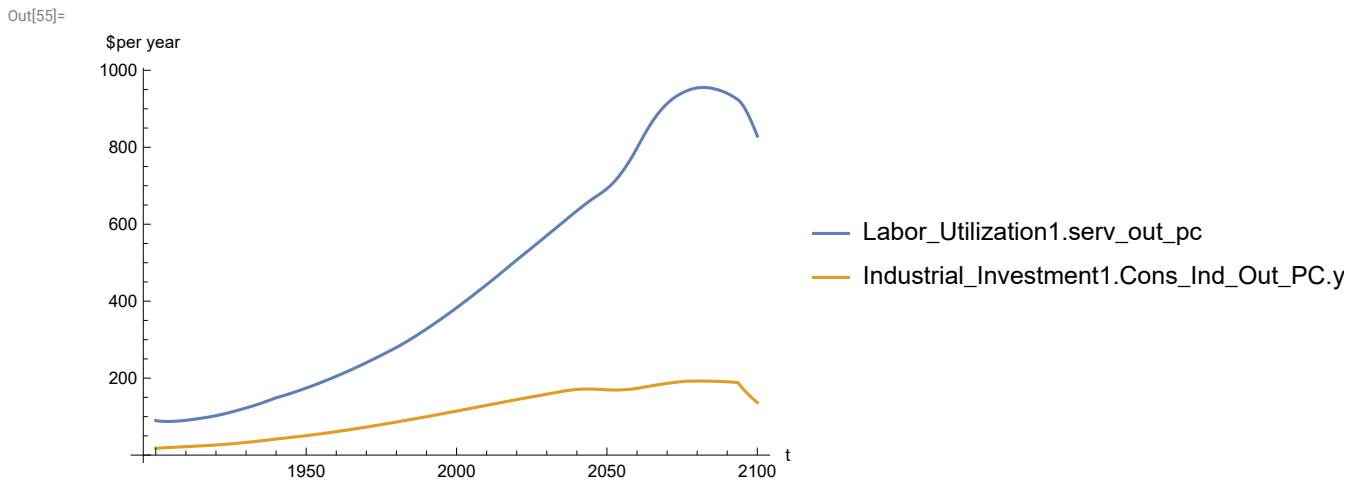
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[54]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

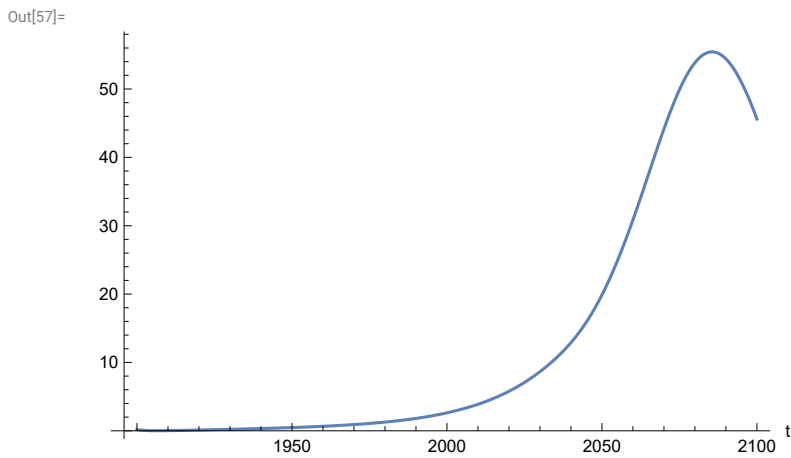
```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 955.428

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

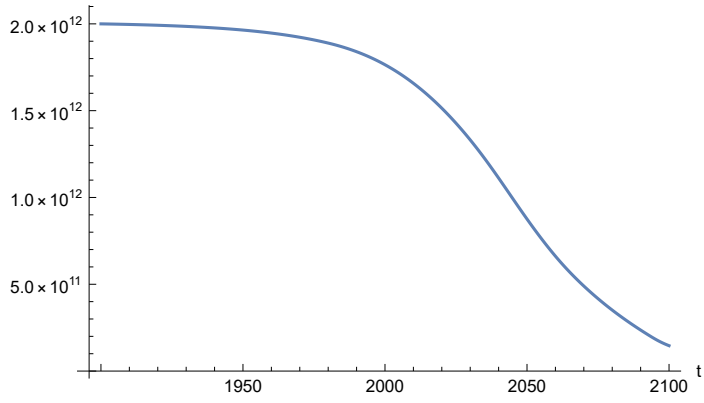
Maximum is 55.4311

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

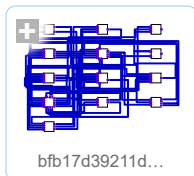


APPENDIX 19. LE/1.01, t_policy_year = 1970. Baseline Scenario 2, Experiment 19.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

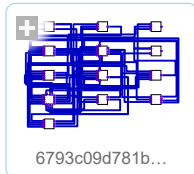
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

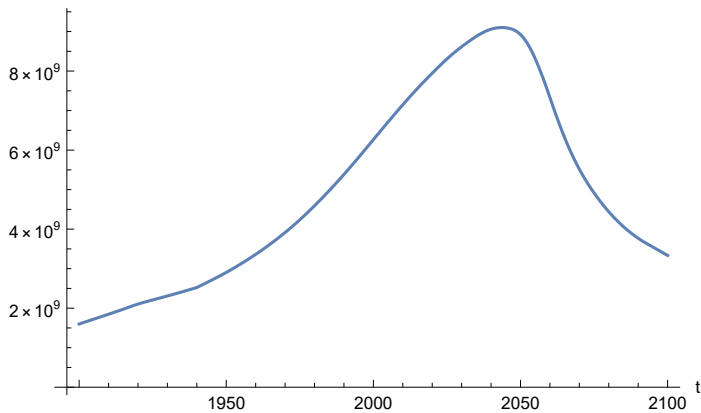
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W6793c09d781b4928aa32ab8e314ac7f7  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

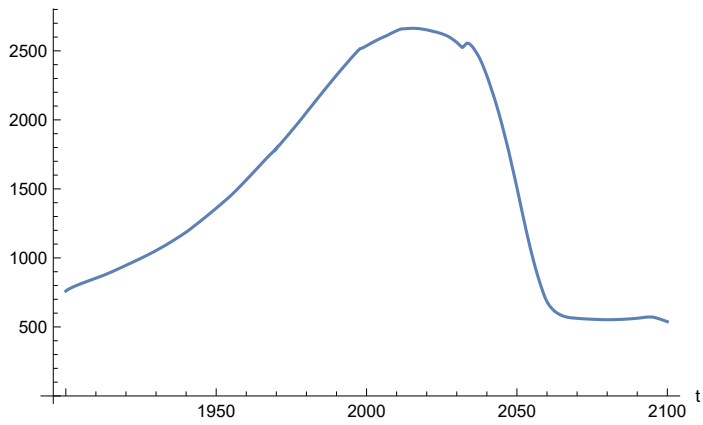
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.10114 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

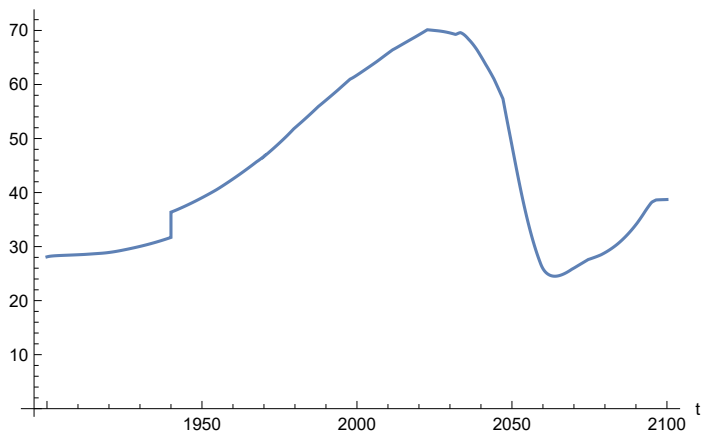
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

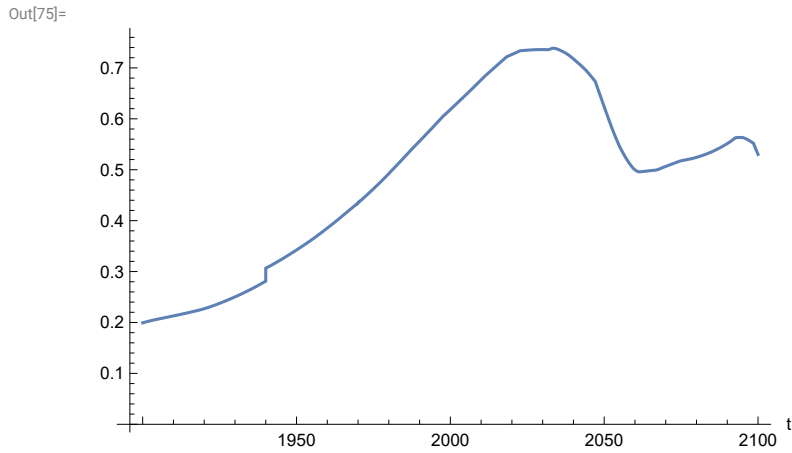
Out[73]=



In[74]:=

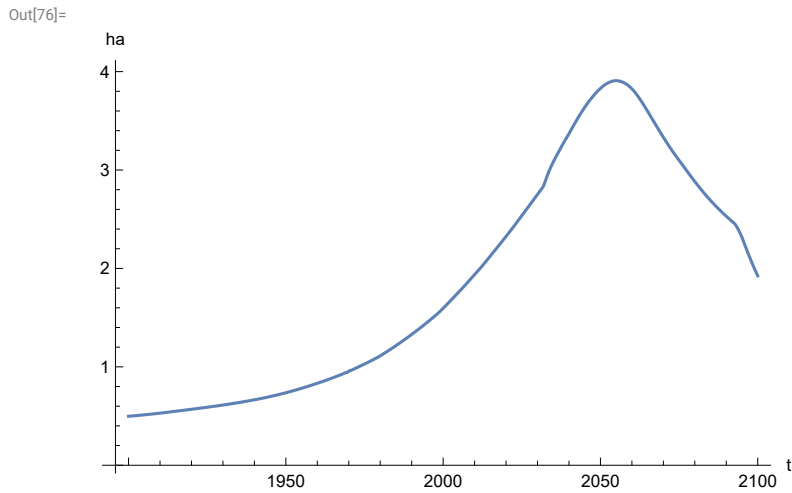
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



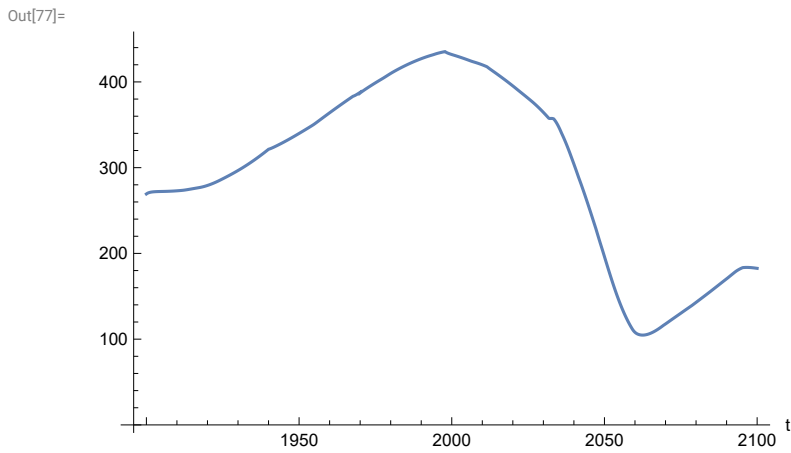
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



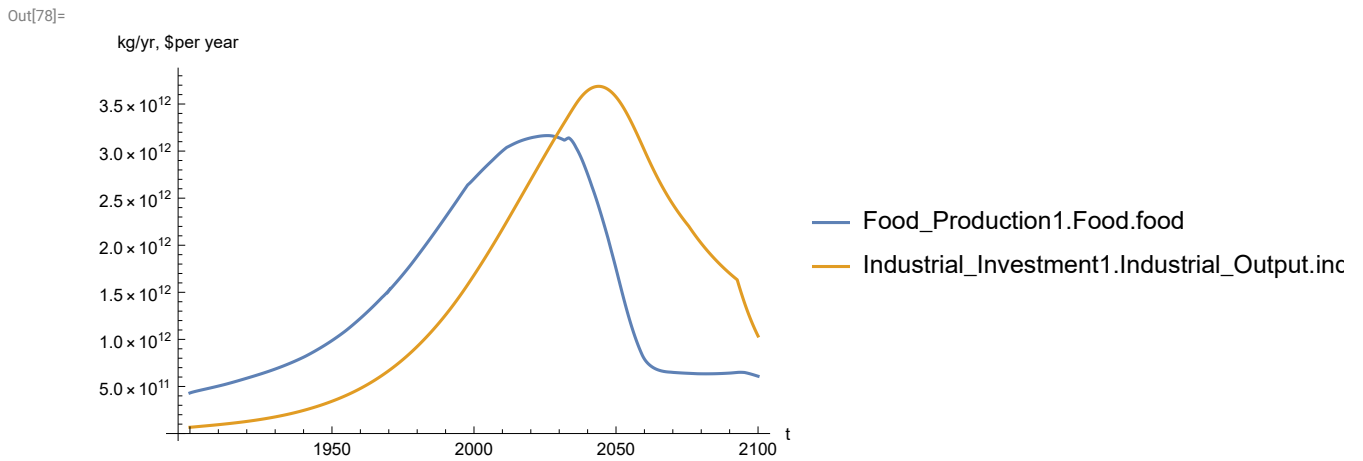
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

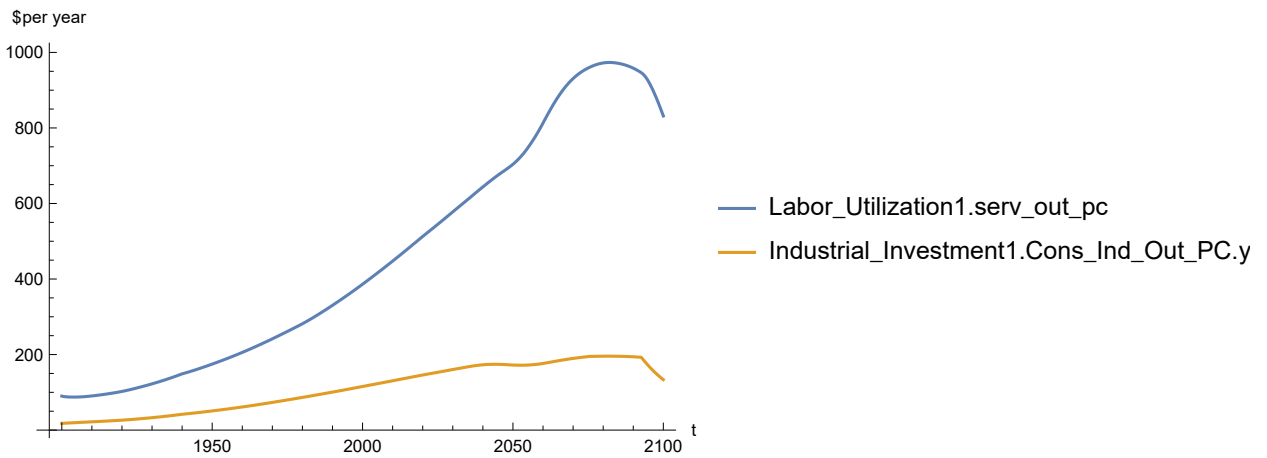
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

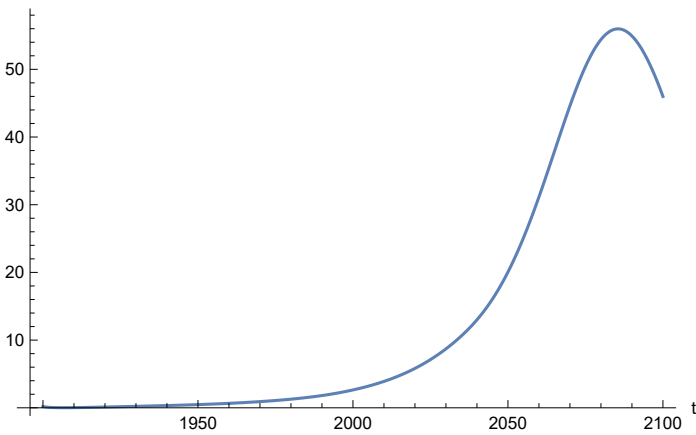
Maximum is 973.4

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

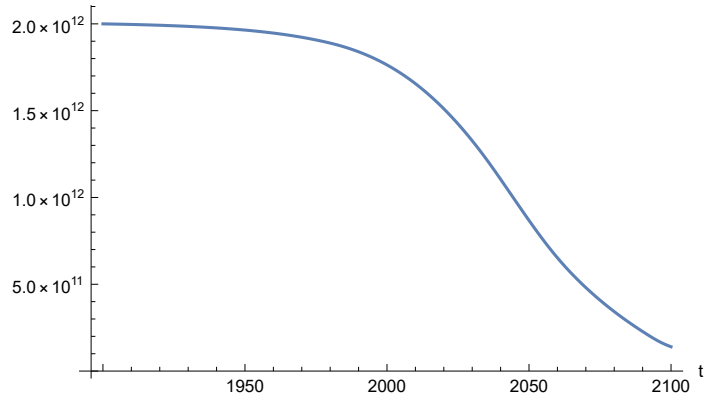
Maximum is 55.9741

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

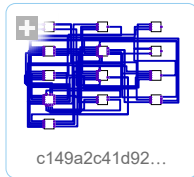
Out[83]=



APPENDIX 20. Baseline Scenario 2, Experiment 20. $LE = LE/1.01$, $t_policy_year = 2025$.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

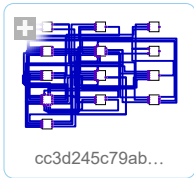
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

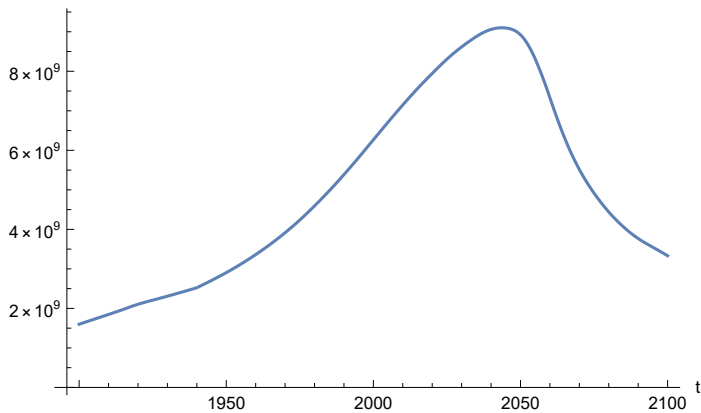
```
Out[93]=
```

```
SystemModelSimulationData [ Model: Wcc3d245c79ab437b9115414706fbe3d7
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[94]=
```



Find max and min of population values.

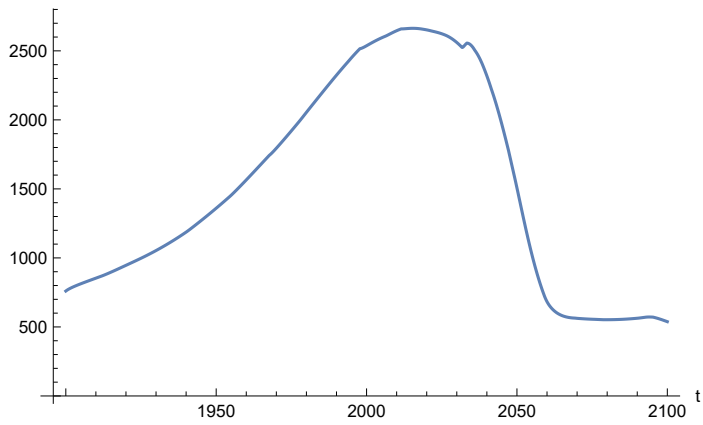
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.101 × 109
```

```
Minimum is 1.6 × 109
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

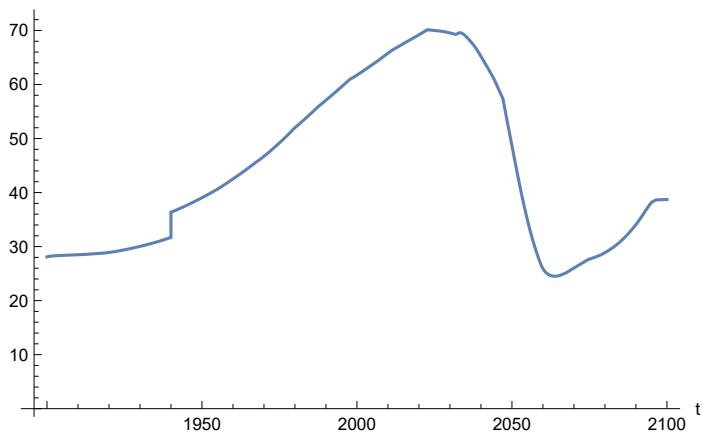
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

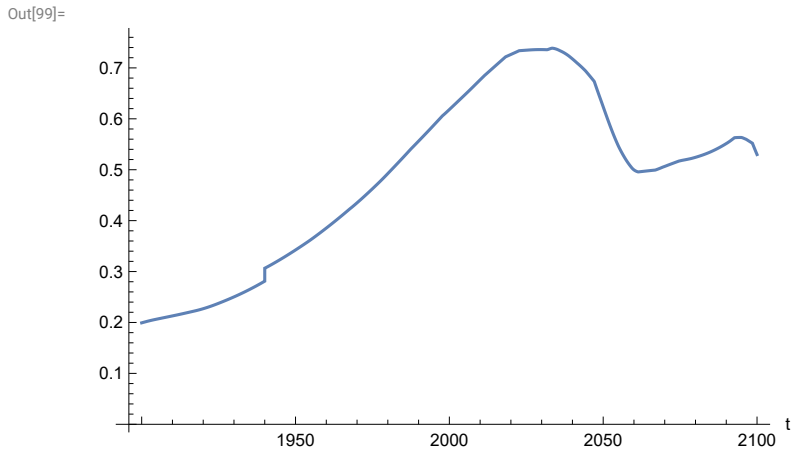
Out[97]=



In[98]:=

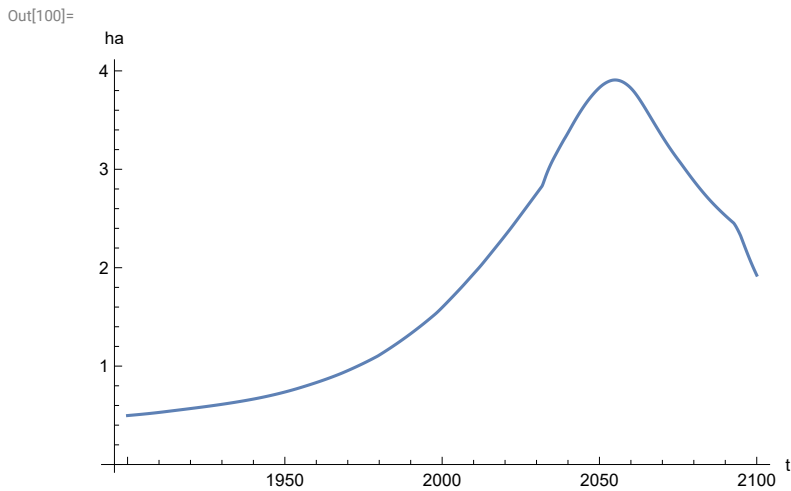
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

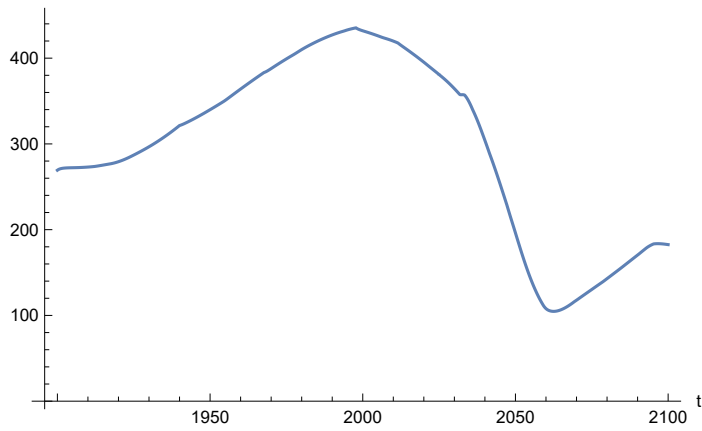


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

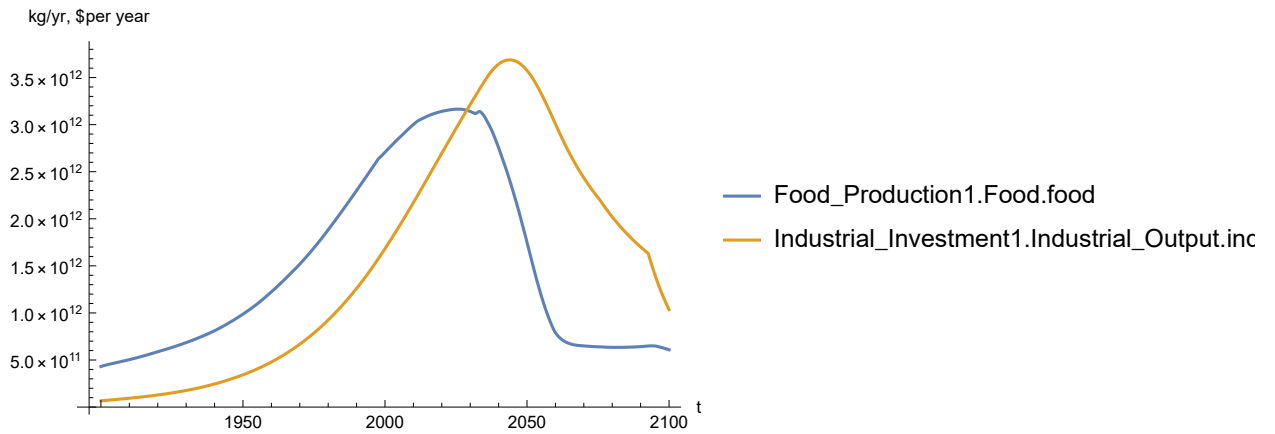


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

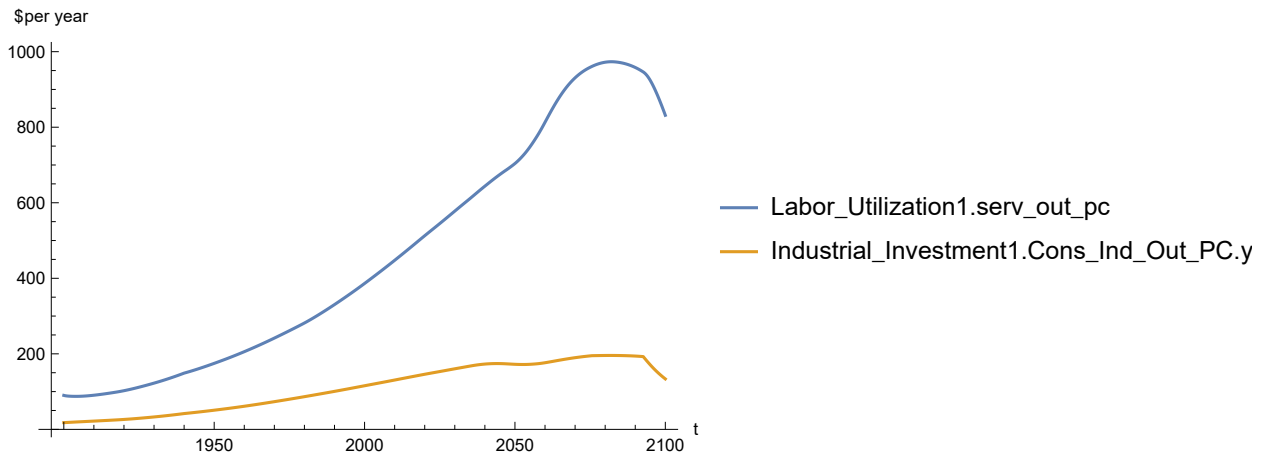


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

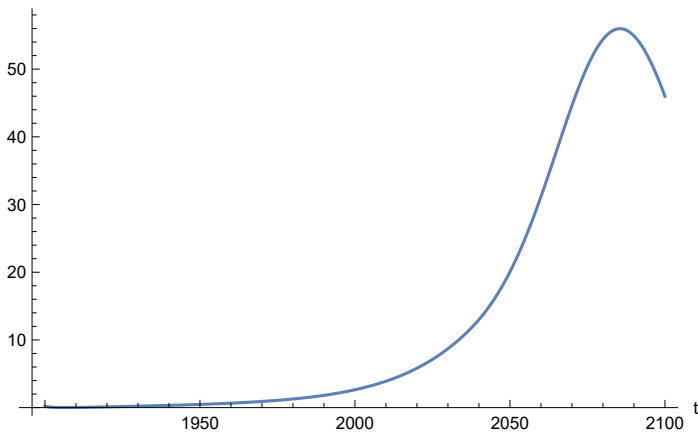
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 973.378
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 55.9708

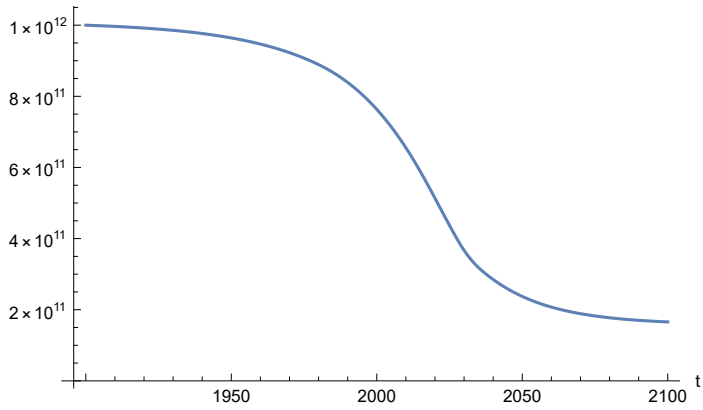
Minimum is 0.0150765

Plot non-renewable resources remaining.

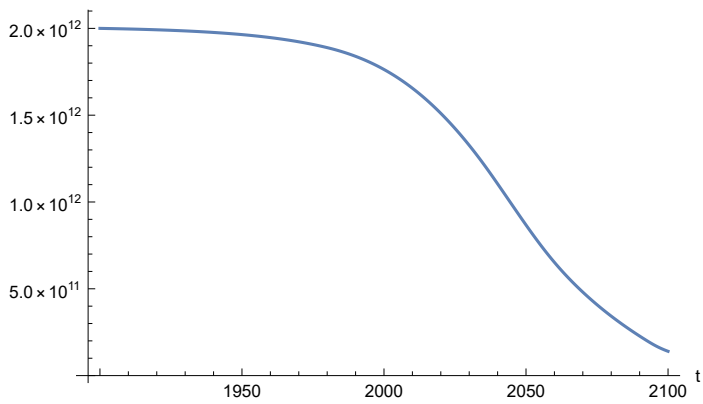
In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

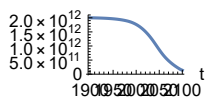
Out[]:=



Out[]:=



Out[107]=



**APPENDIX 21. BENCHMARK SCENARIO 2, Experiment 21. $LE = LE/1.03$, $t_{policy_year} = 1970$.
Last modified: 23 July 2022/0915 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

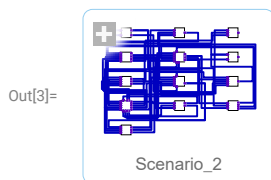
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

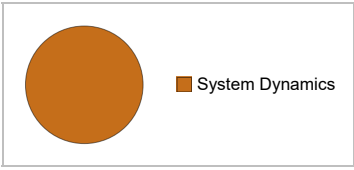
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 2.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_2"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_2
	Description	More abundant non-recoverable natural resources
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	Summary	265
	Summary	265
	Description	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

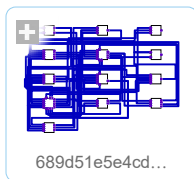
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

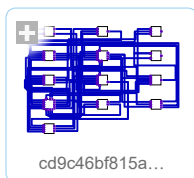
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```



```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

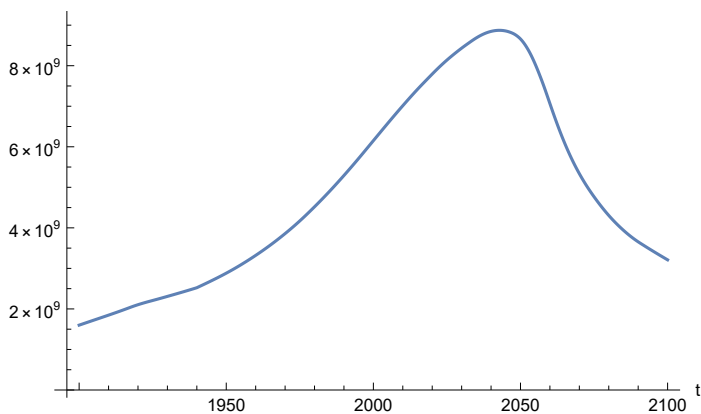
```
Out[21]=
```

```
SystemModelSimulationData [   Model: Wcd9c46bf815a4bb18486c71f2d962672
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

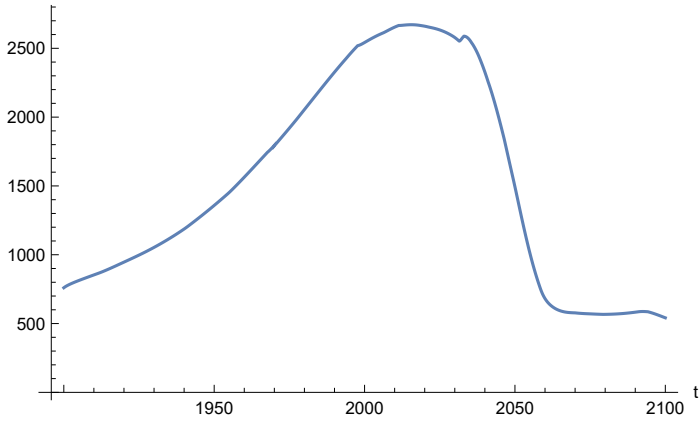
```
Out[22]=
```



Find max and min of population values.

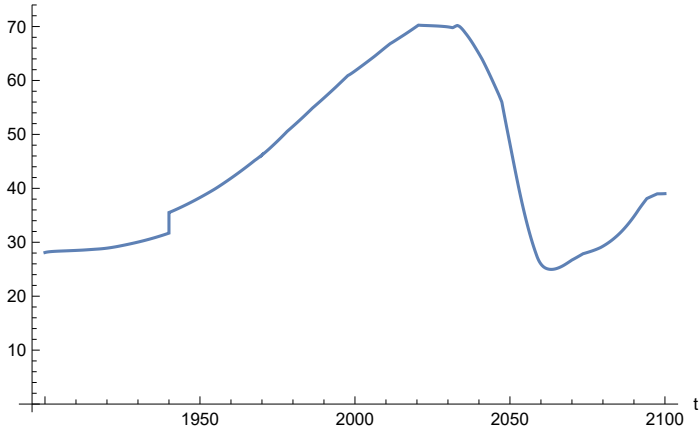
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.87263 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```

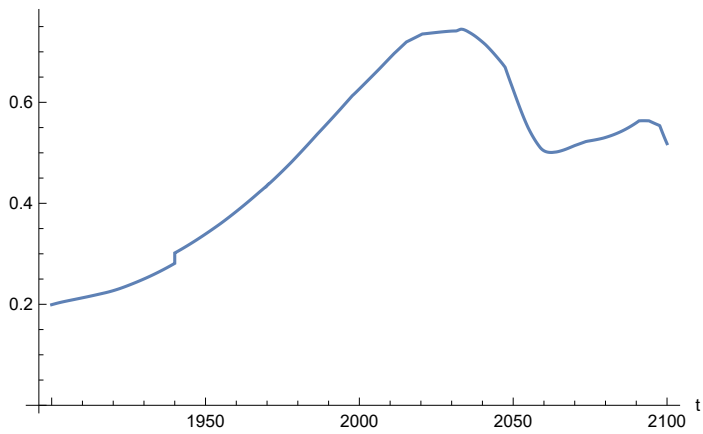


```
In[26]:=
```

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,  
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

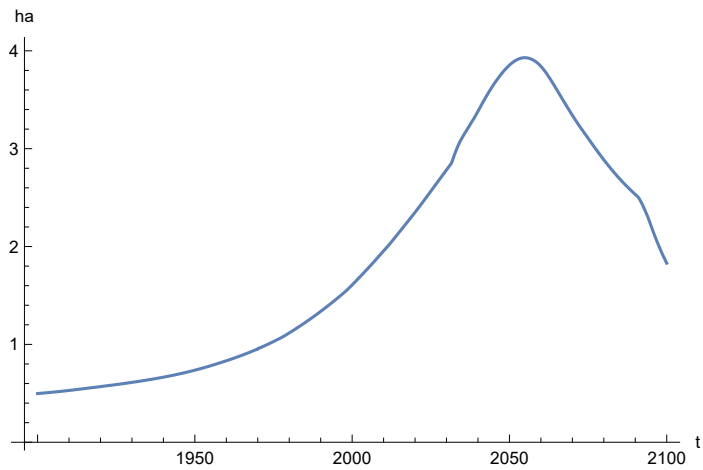
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,  
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
 _footprint"}]
```

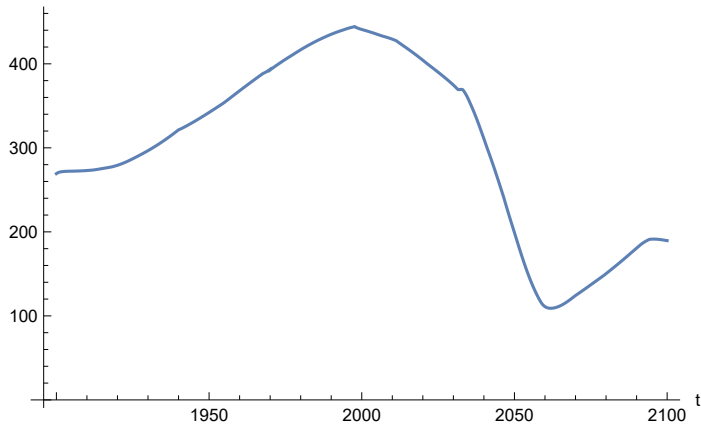
Out[28]=



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

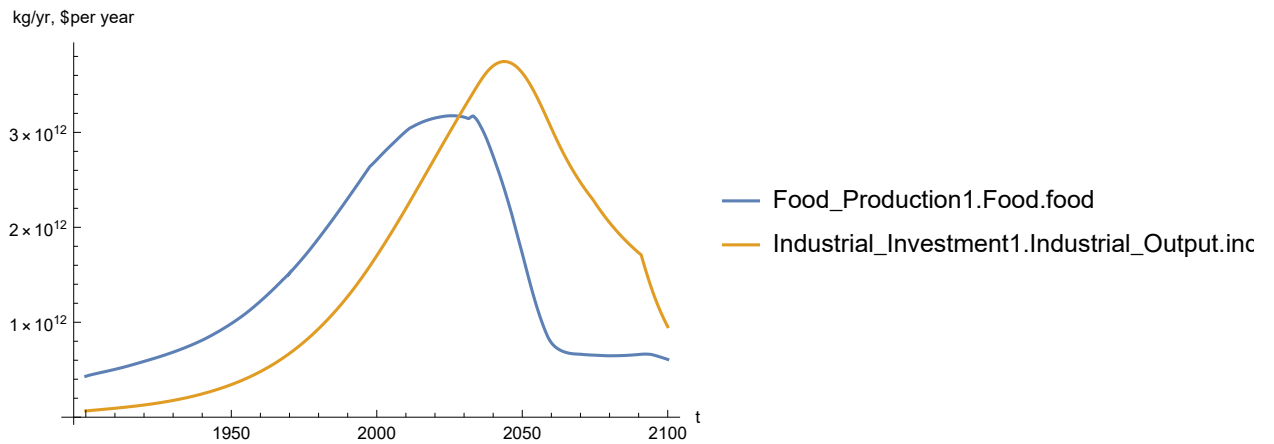
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

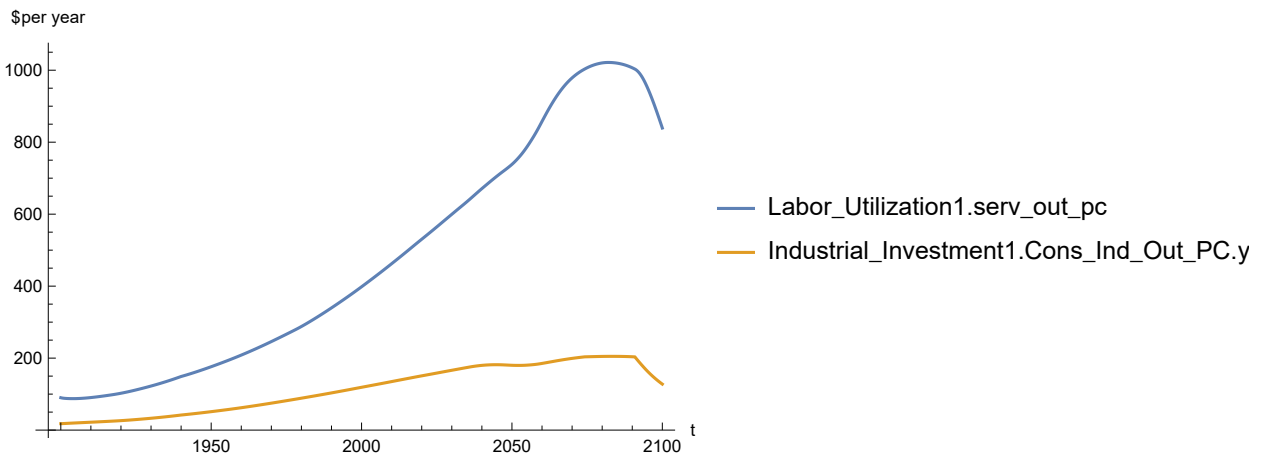
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

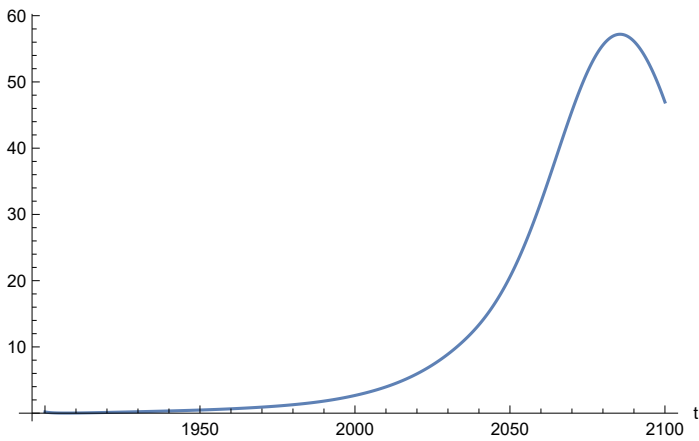
Maximum is 1021.52

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

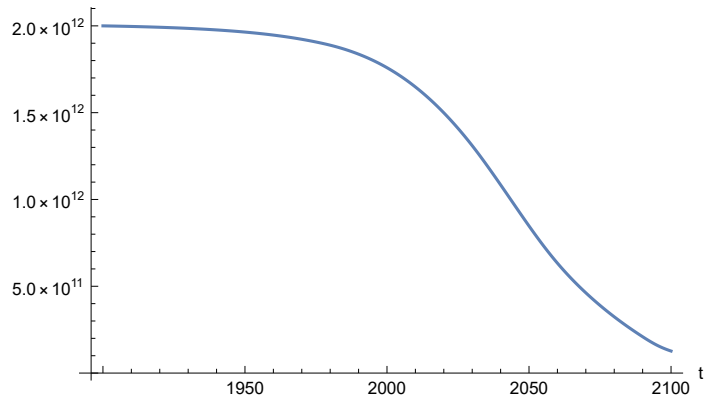
Maximum is 57.1973

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

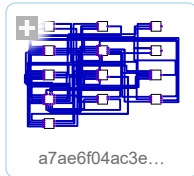


APPENDIX 22. LE/1.03, t_policy_year = 2025. Baseline Scenario 2, Experiment 22.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

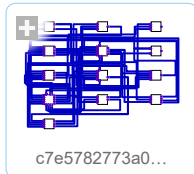
```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

```
Out[44]=
```



Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

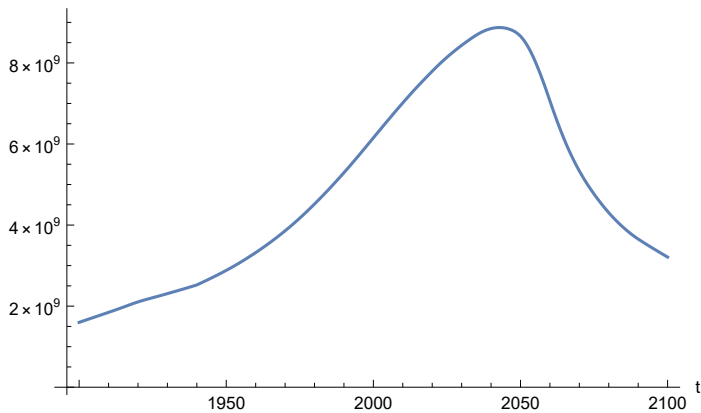
```
Out[45]=
```

```
SystemModelSimulationData [  Model: Wc7e5782773a04110a584f4c4318ab645  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[46]=
```



Find max and min of population values.

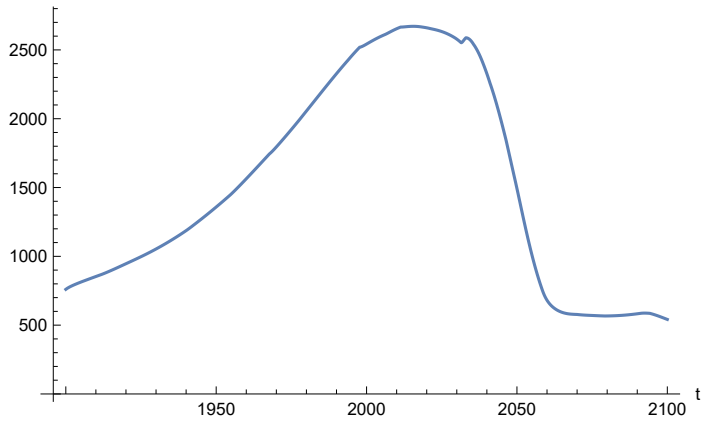
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.87253 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

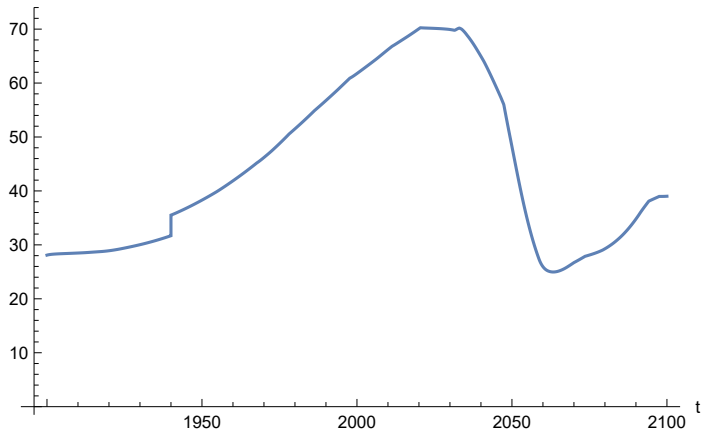
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

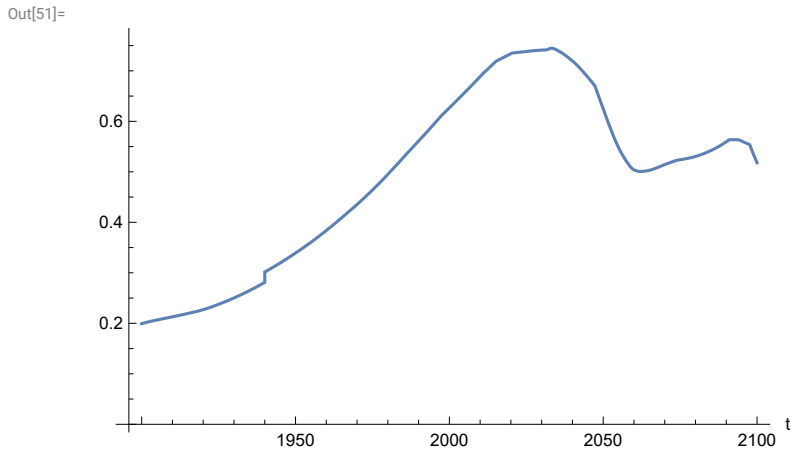
Out[49]=



In[50]:=

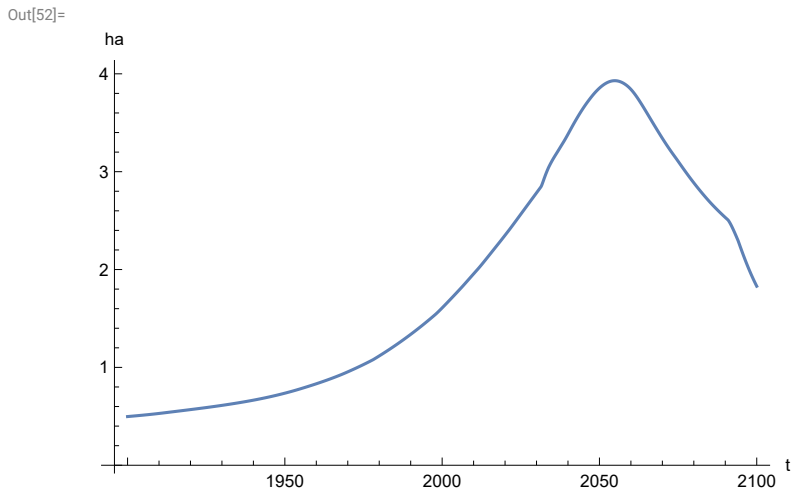
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



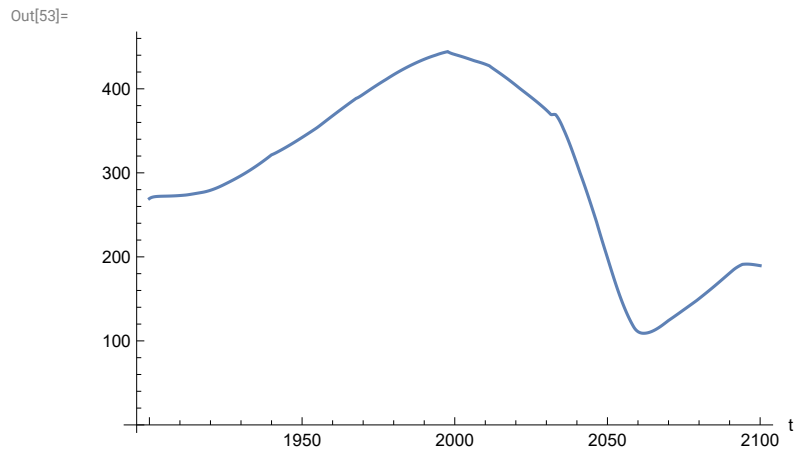
Plot per capita ecological footprint, hectares.

```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



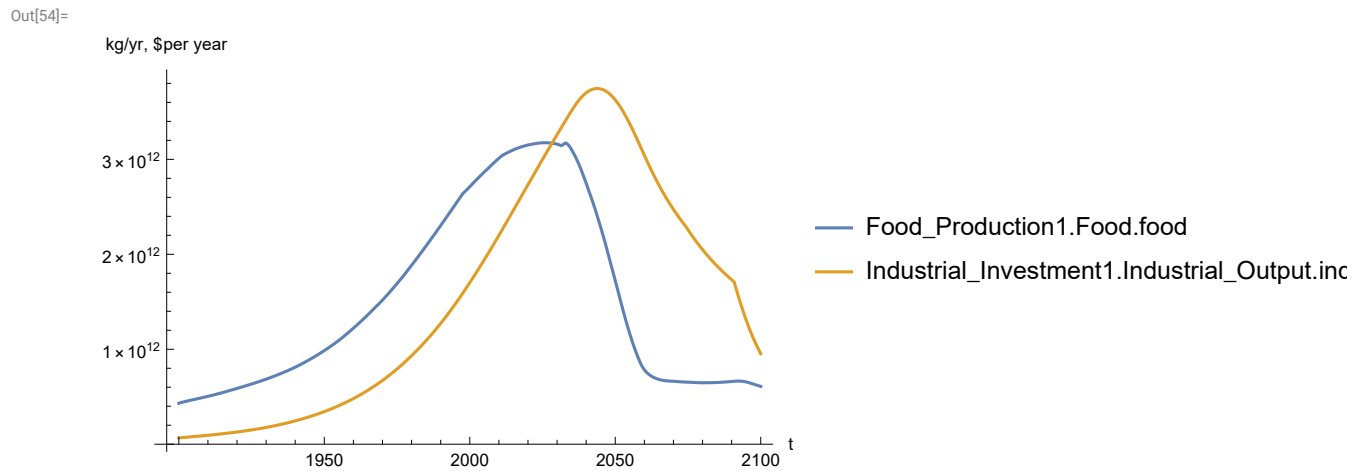
Plot food production per capita (kg/year).

```
In[53]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



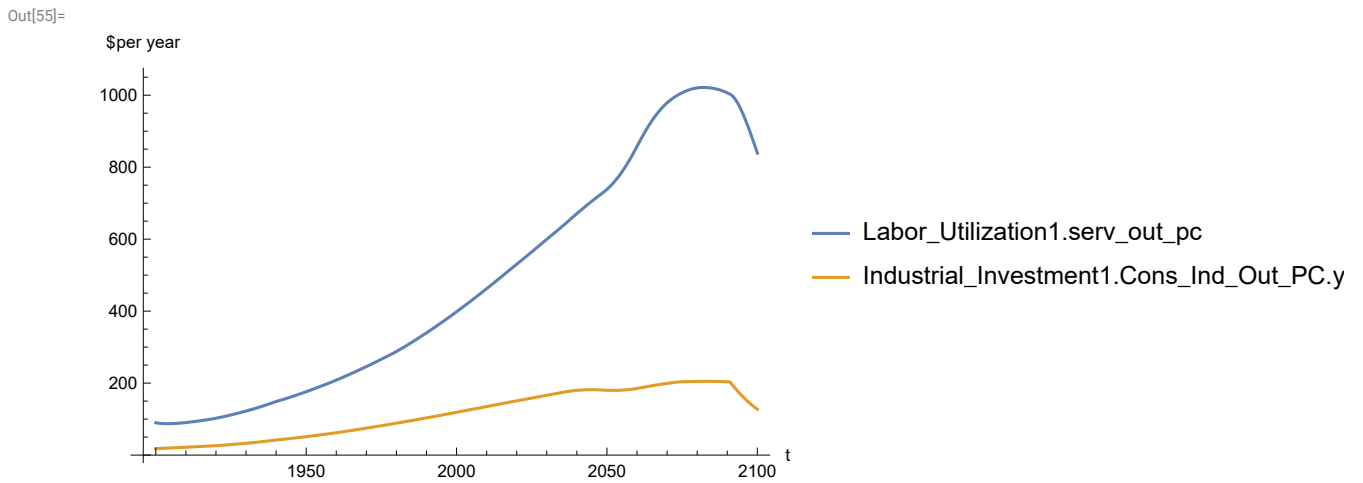
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[54]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

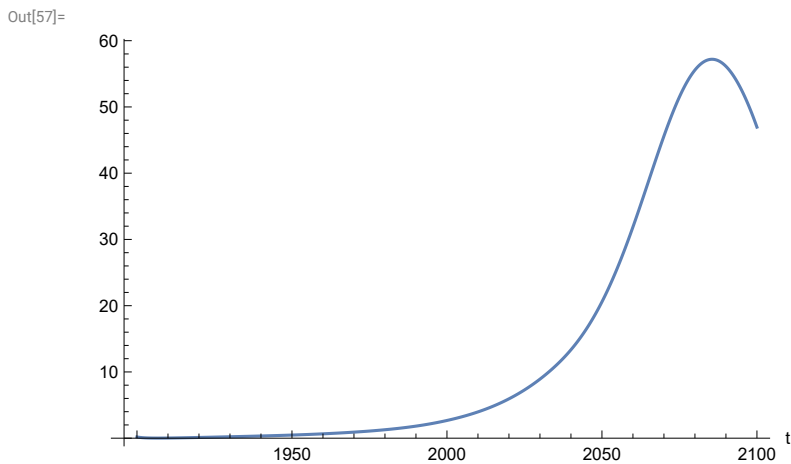
```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1021.49

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

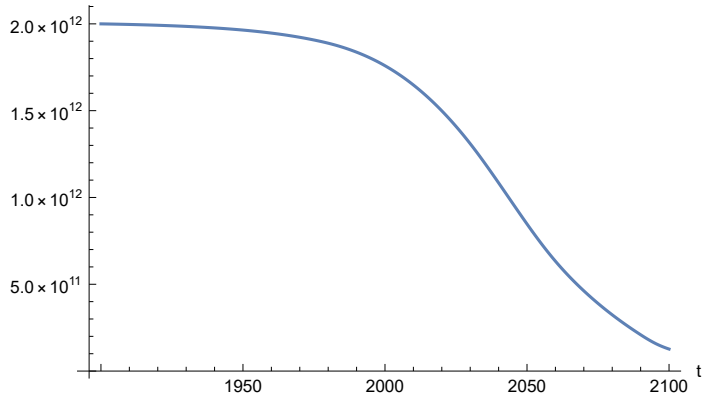
Maximum is 57.1938

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

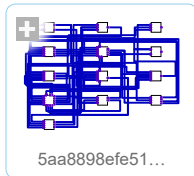


APPENDIX 23. LE/1.05, t_policy_year = 1970. Baseline Scenario 2, Experiment 23.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

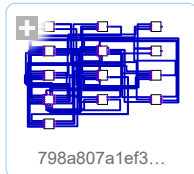
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

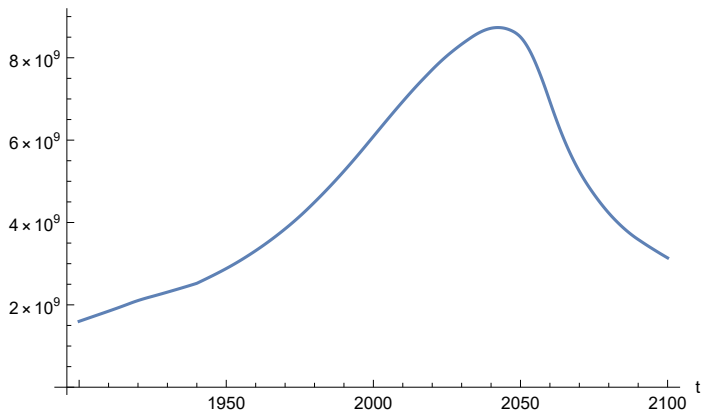
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W798a807a1ef3420586b9f8dd24c14582  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

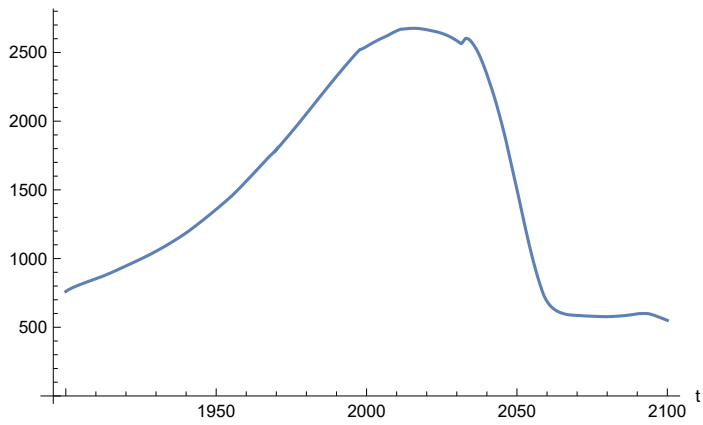
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.73385 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

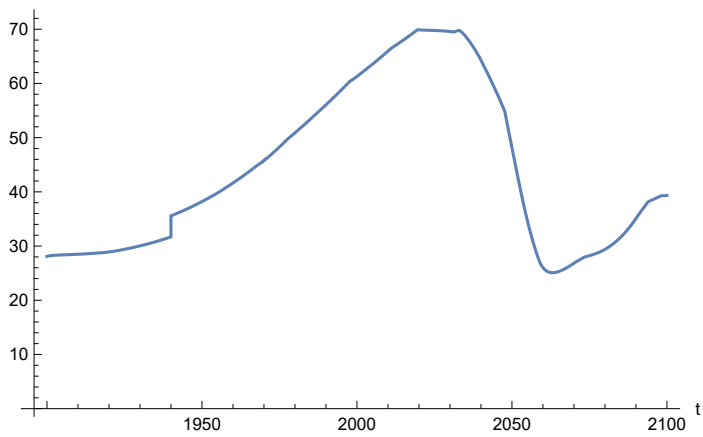
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

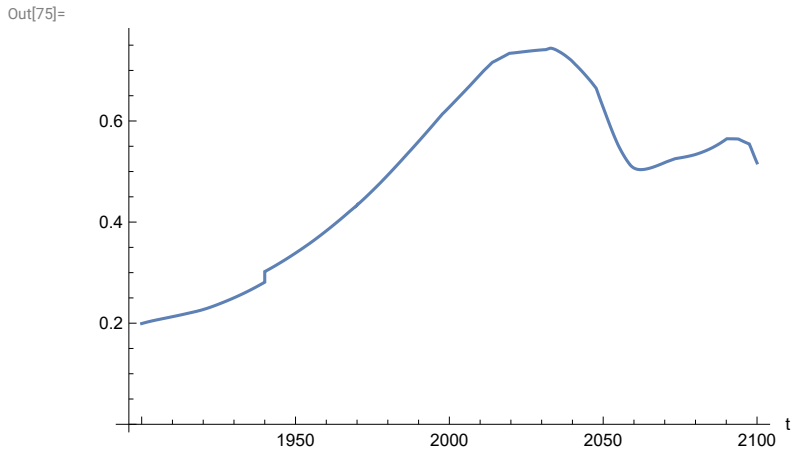
Out[73]=



In[74]:=

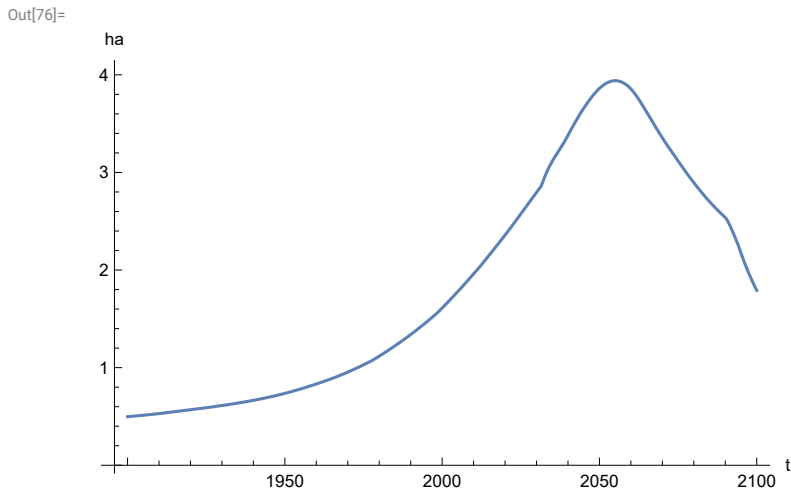
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

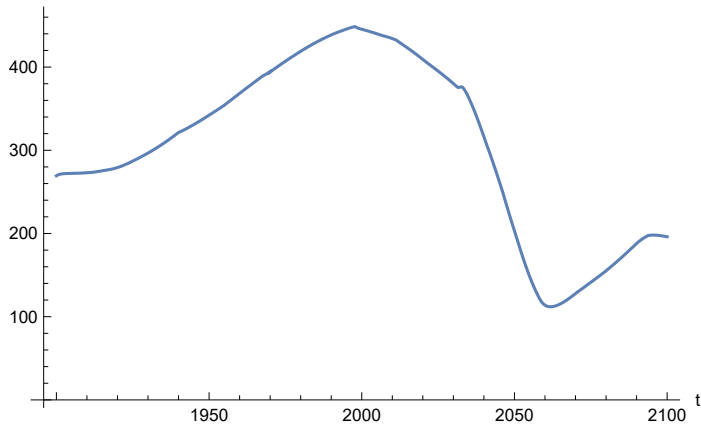
```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[77]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

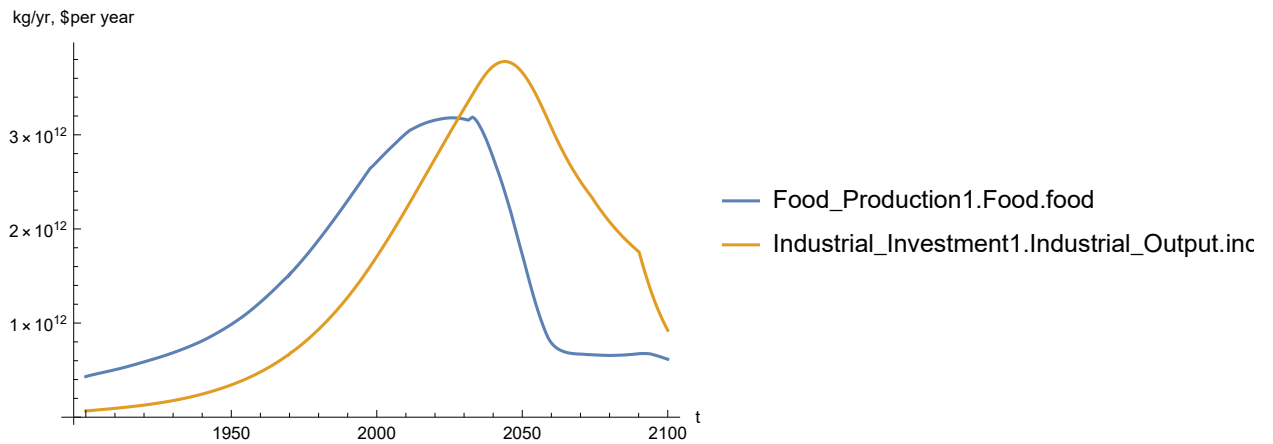
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[78]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

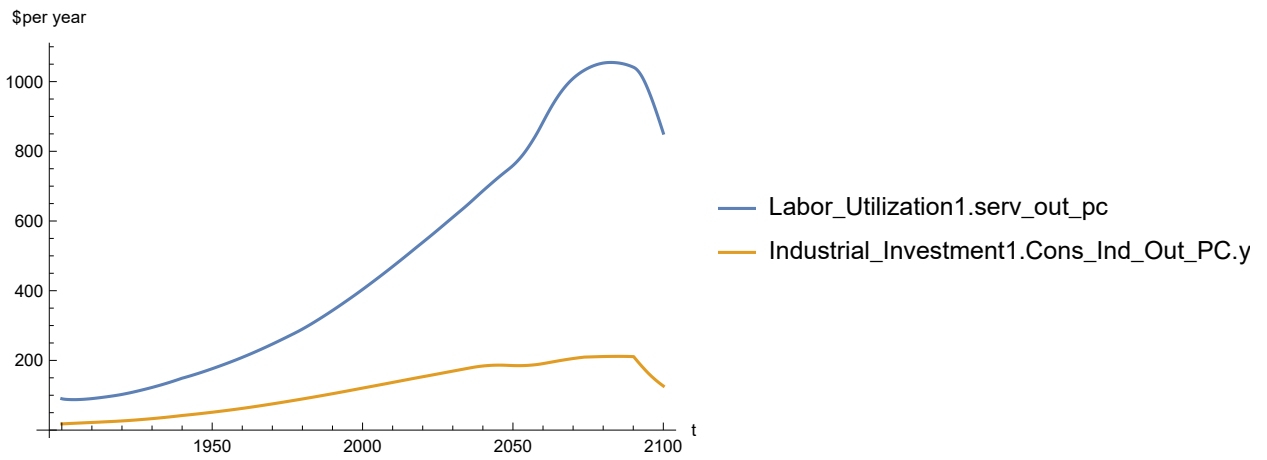
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

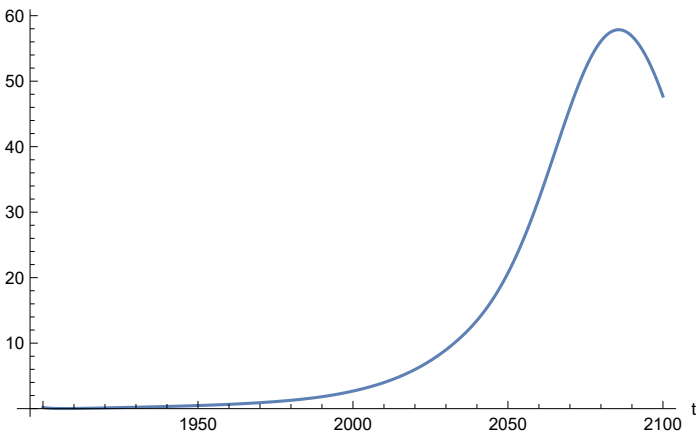
Maximum is 1054.95

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

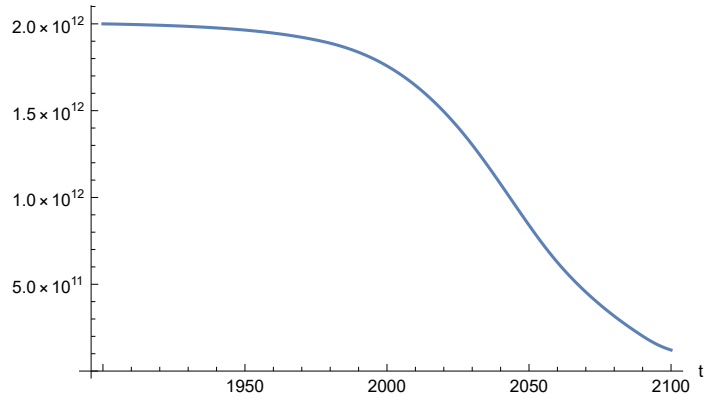
Maximum is 57.8555

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

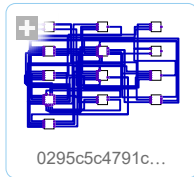
Out[83]=



APPENDIX 24. Baseline Scenario 2, Experiment 24. LE = LE/1.05, t_policy_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

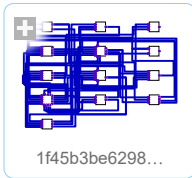
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



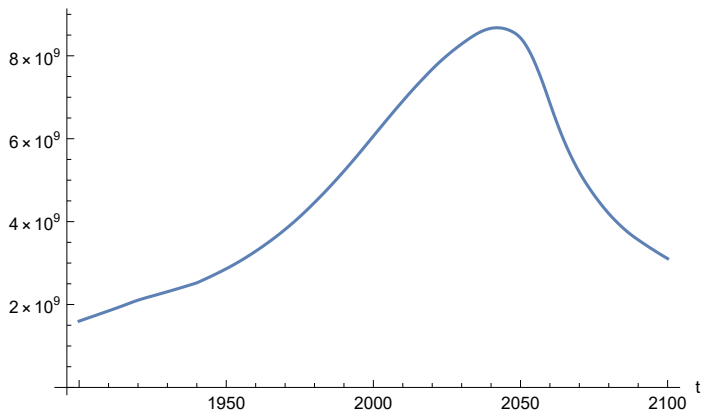
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

```
SystemModelSimulationData [ Model: W1f45b3be6298493b8a87de1fe1483809
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

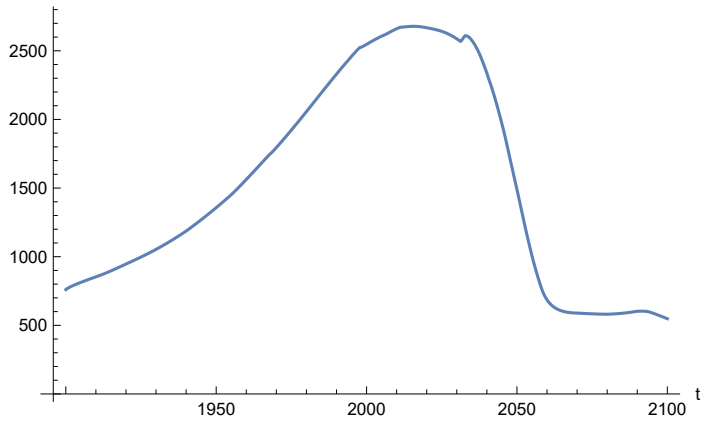


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is 8.67626 × 109
Minimum is 1.6 × 109
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

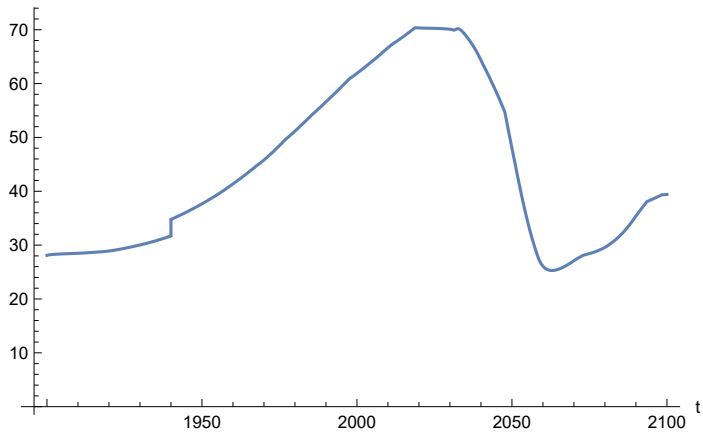
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

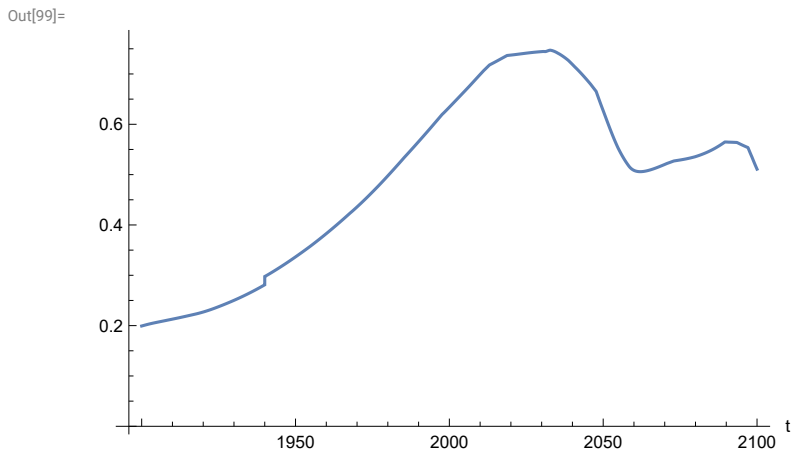
Out[97]=



In[98]:=

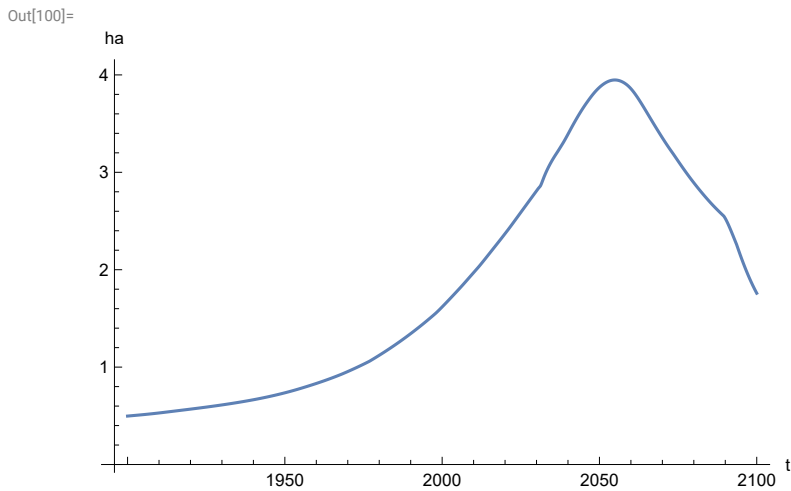
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

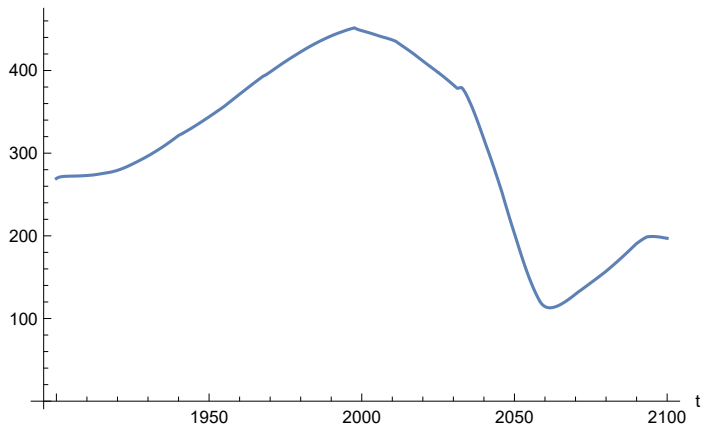


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

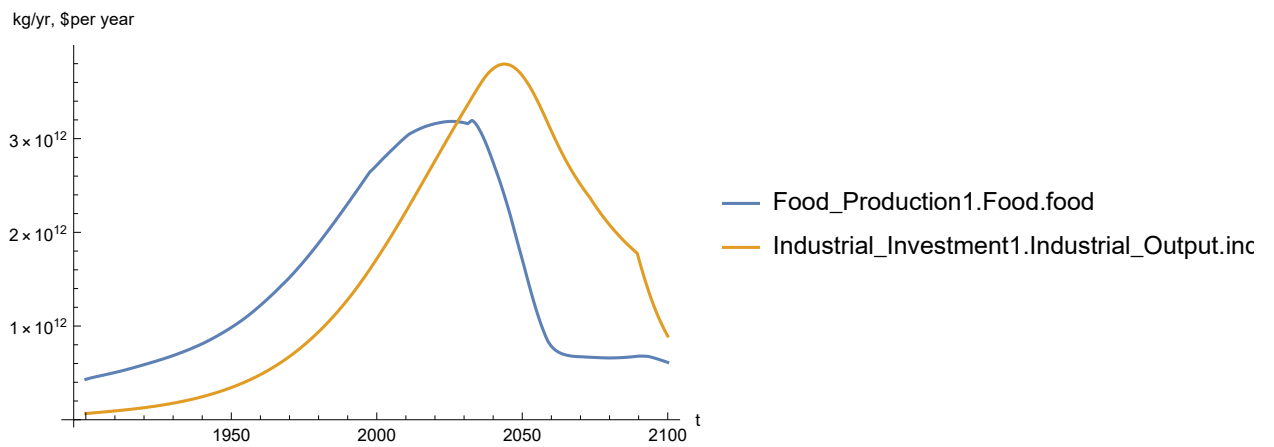


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

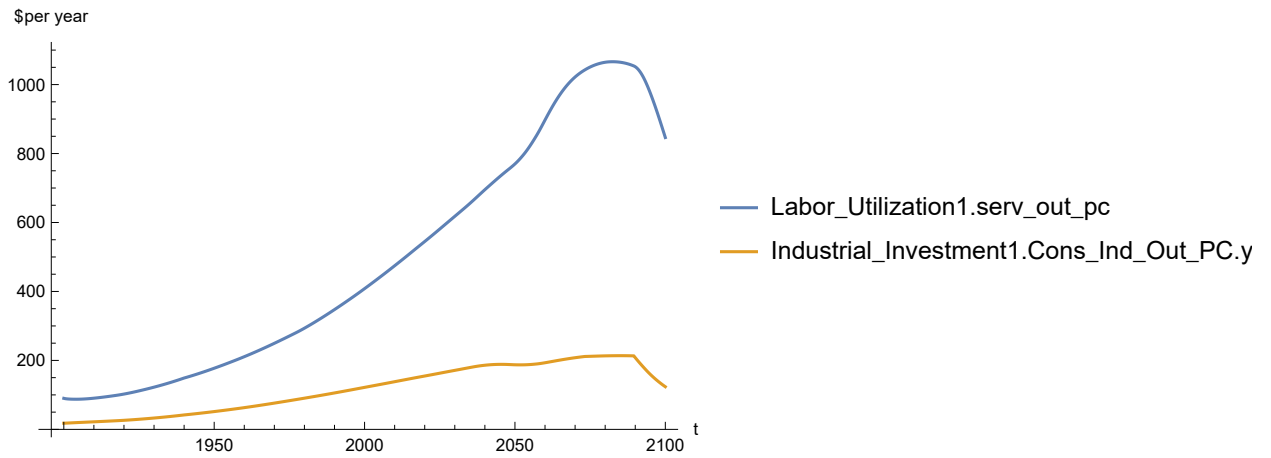


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

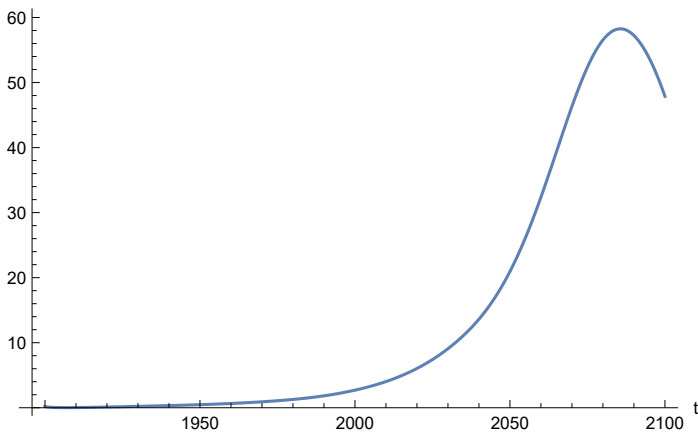
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 1066.27
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 58.2592

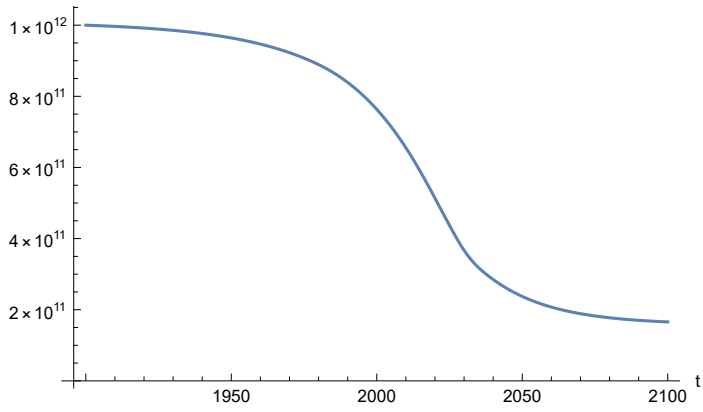
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[107]=



**APPENDIX 25. BENCHMARK SCENARIO 2, Experiment 15. $LE = LE/1.1$, $t_policy_year = 1970$.
Last modified: 23 July 2022/0940 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

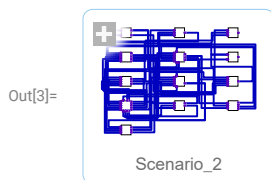
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

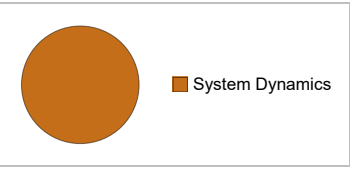
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 2.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_2"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_2
	Description	More abundant non-recoverable natural resources
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background Color	True
Out[4]=	Simulation Start Year	265
	Simulation End Year	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

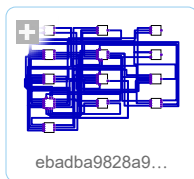
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

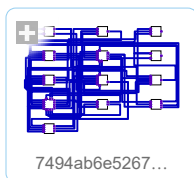
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

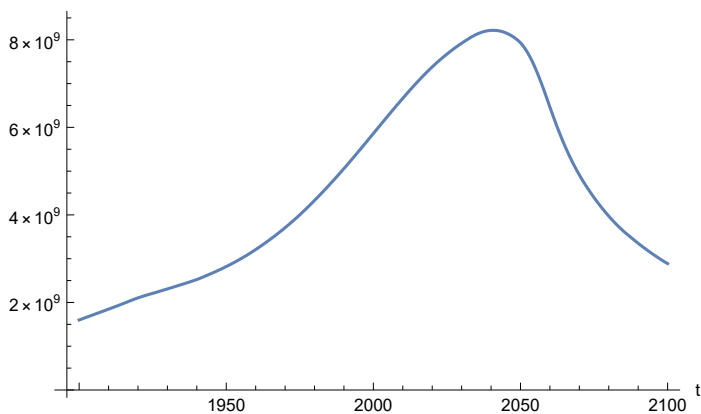
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W7494ab6e526742de9729cae79e5210c5  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

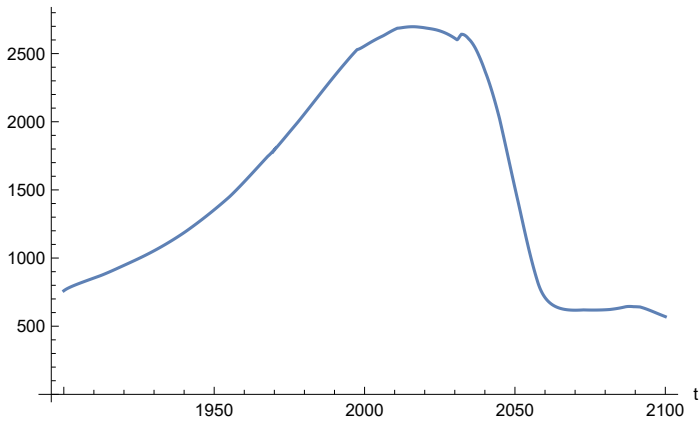
```
Out[22]=
```



Find max and min of population values.

```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.21687 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

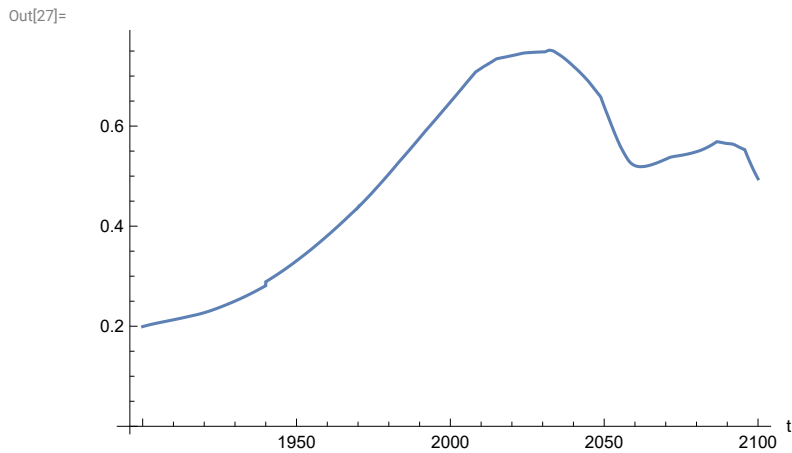
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```



```
In[26]:=
```

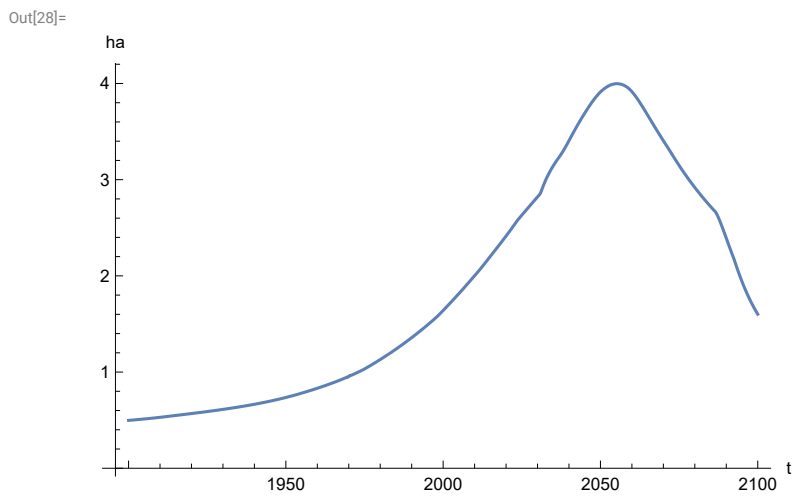
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

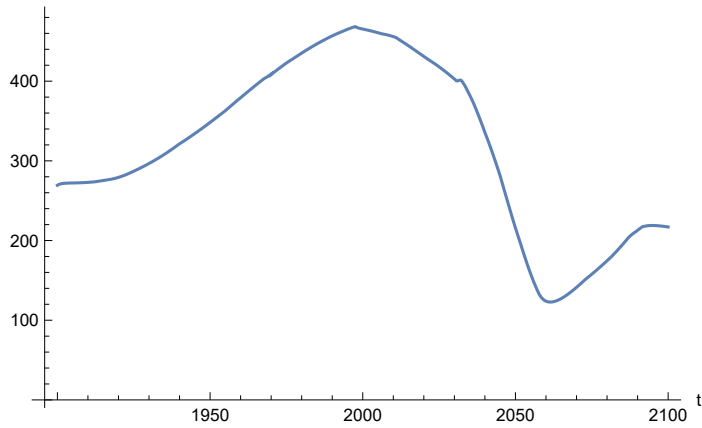
```
In[28]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

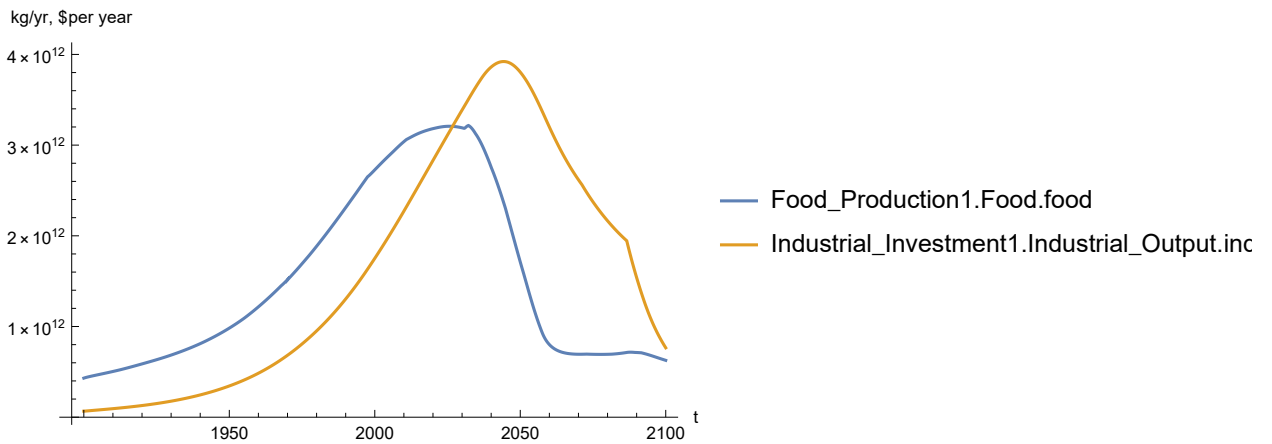
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

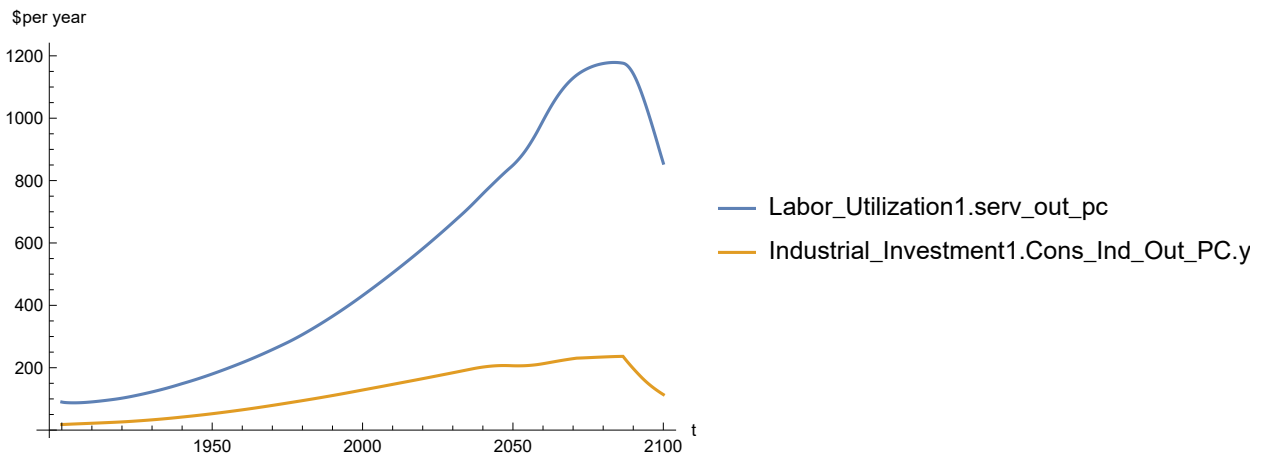
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

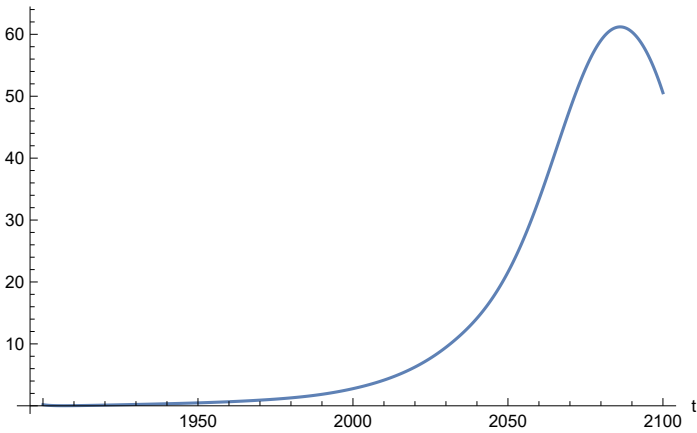
Maximum is 1178.74

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

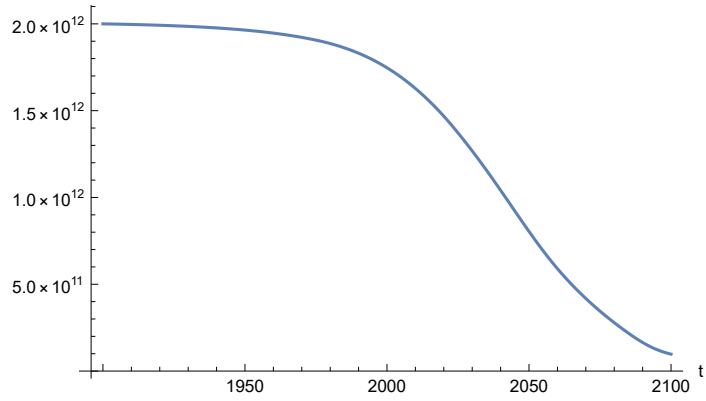
Maximum is 61.2013

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

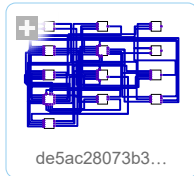


APPENDIX 26. LE/1.1, t_policy_year = 2025. Baseline Scenario 2, Experiment 26.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

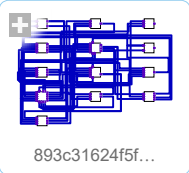
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
```

Out[44]=  893c31624f5f...

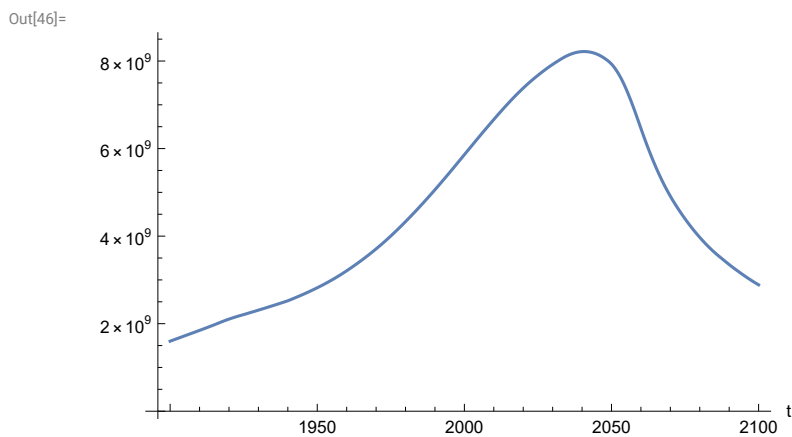
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W893c31624f5f41669ade669f4b4b99a3
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

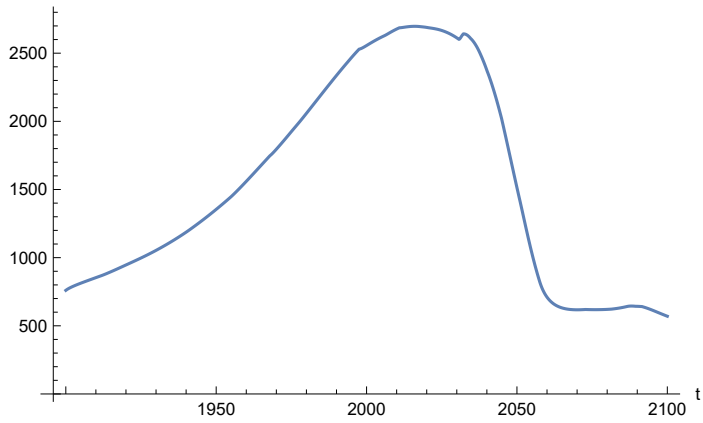
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.21685×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

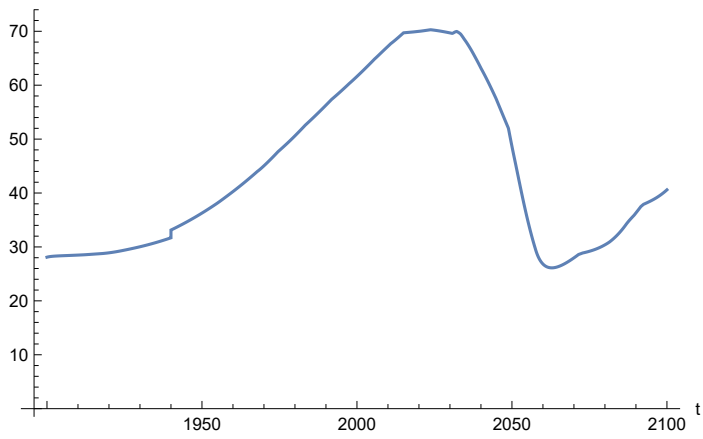
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

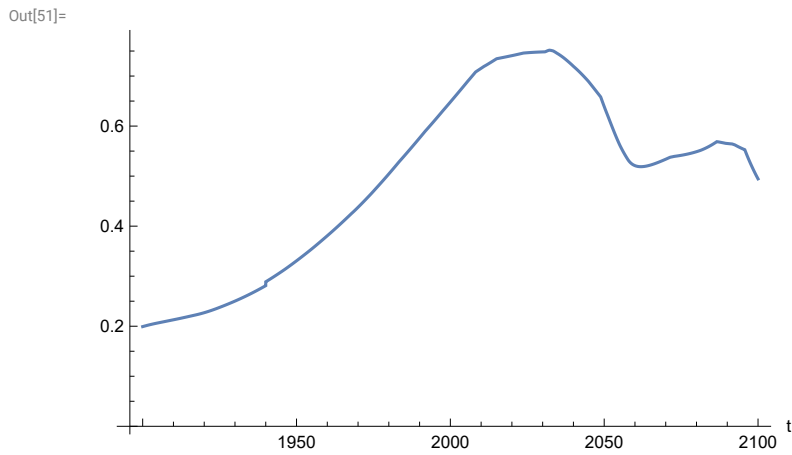
Out[49]=



In[50]:=

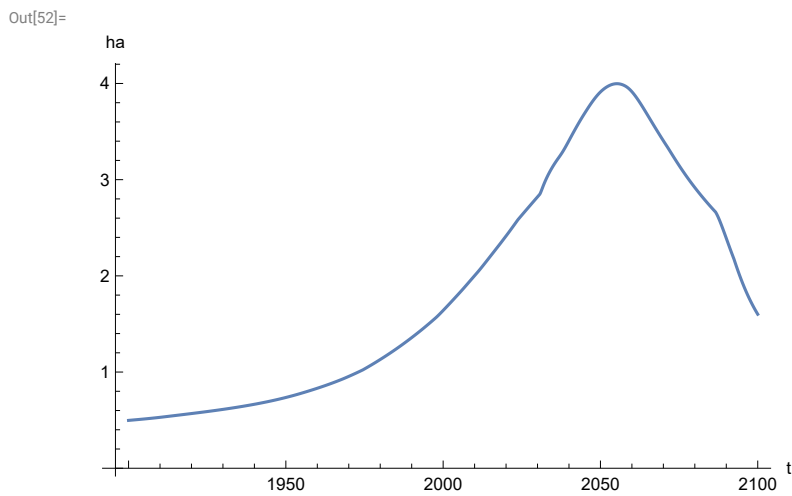
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



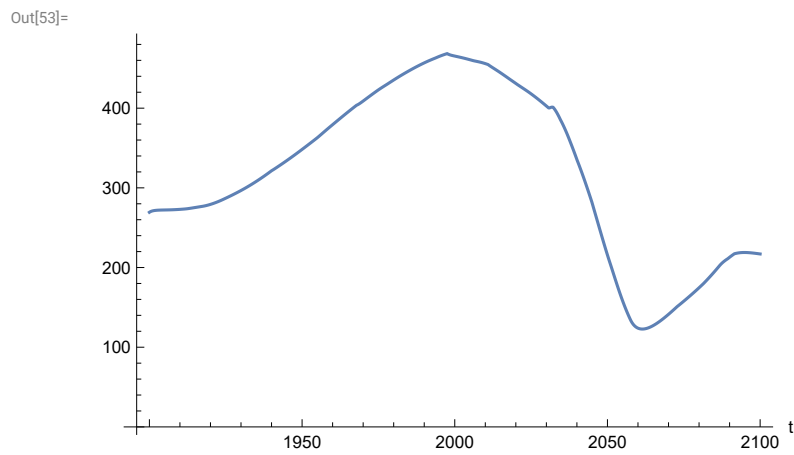
Plot per capita ecological footprint, hectares.

```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



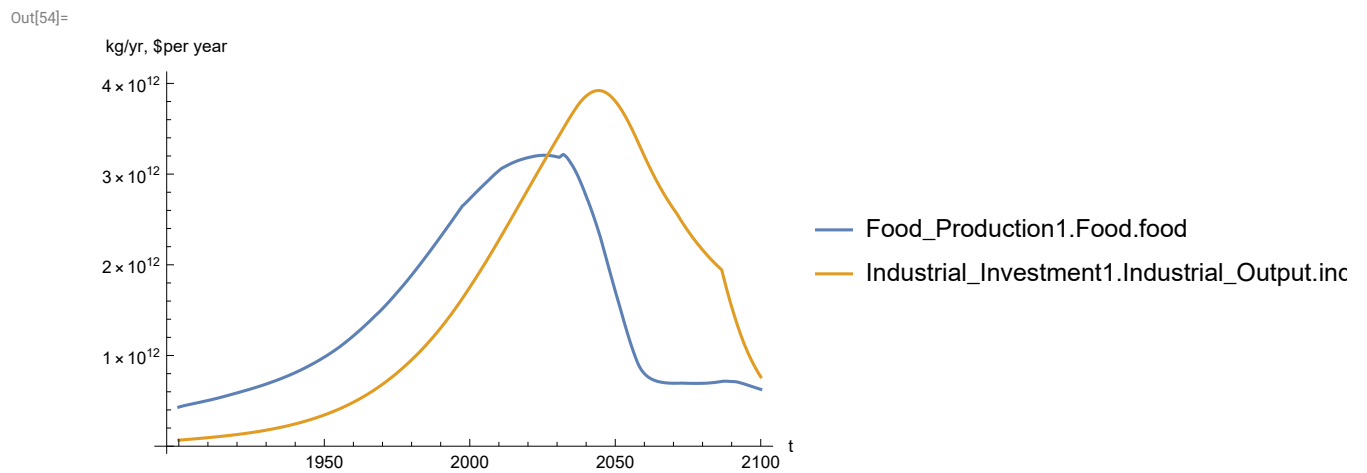
Plot food production per capita (kg/year).

```
In[53]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



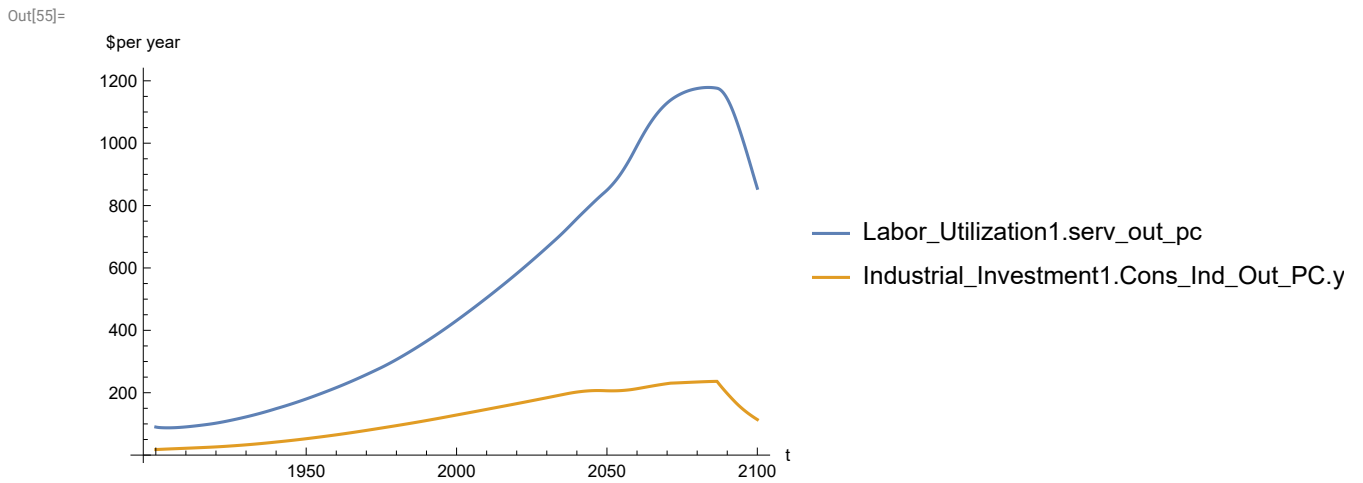
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[54]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

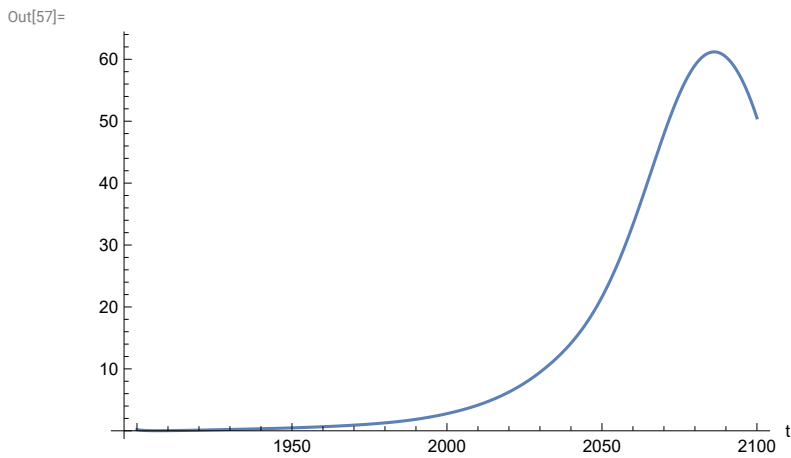
```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1178.69

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

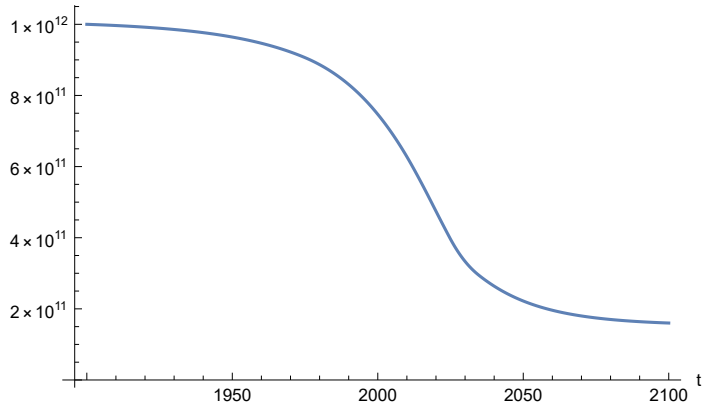
Maximum is 61.1967

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=



APPENDIX 27. BENCHMARK SCENARIO 3, Experiment 27. `t_policy_year = 2002.`

Last modified: 28 July 2022/1030 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

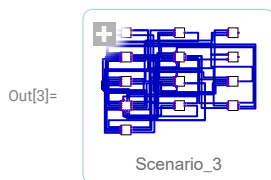
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

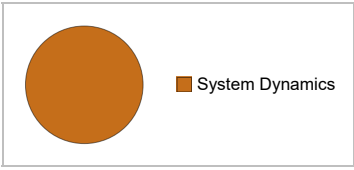
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 3.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_3"]
```



In[4]:= **mysummary = mysim["Summary"]**

	Model	SystemDynamics.WorldDynamics.World3.Scenario_3
	Description	More accessible non-recoverable natural resources and pollution control
	Simulation Interval	True
	Policy Year	0
	Control Cost	106
	Base Case	True
Out[4]=	Simulation Length	265
	Simulation Length	265
	Description	

Show the default value of `t_policy_year`.

In[5]:= **SystemModel[mysim][{"ParameterValues", "t_policy_year"}]**

Out[5]= {t_policy_year → 2002}

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

In[6]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[7]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[8]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[9]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute Benchmark Scenario 3 and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

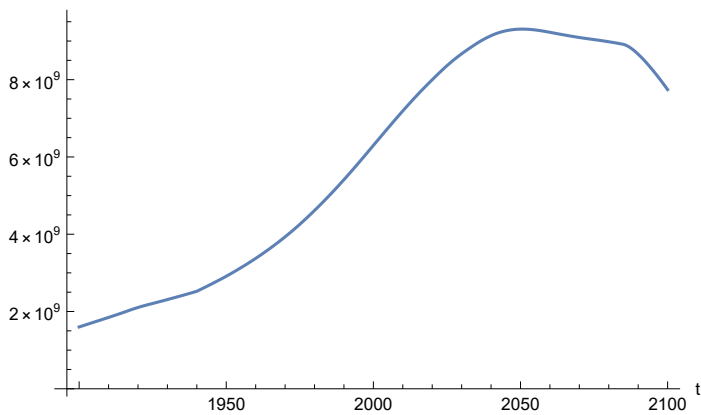
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Scenario_3
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

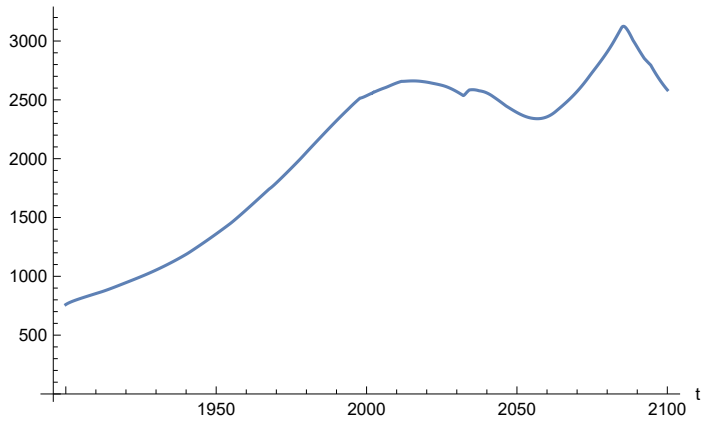
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.30865 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

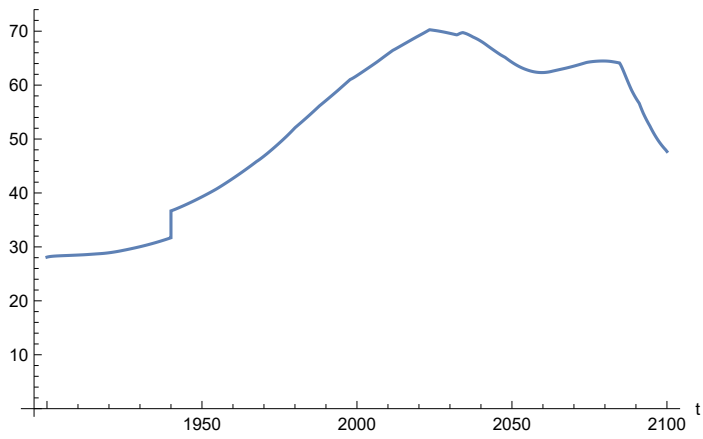
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

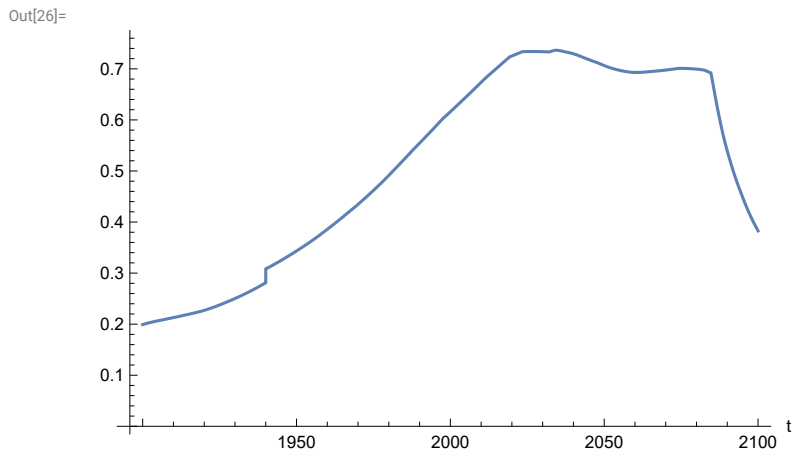
Out[24]=



In[25]:=

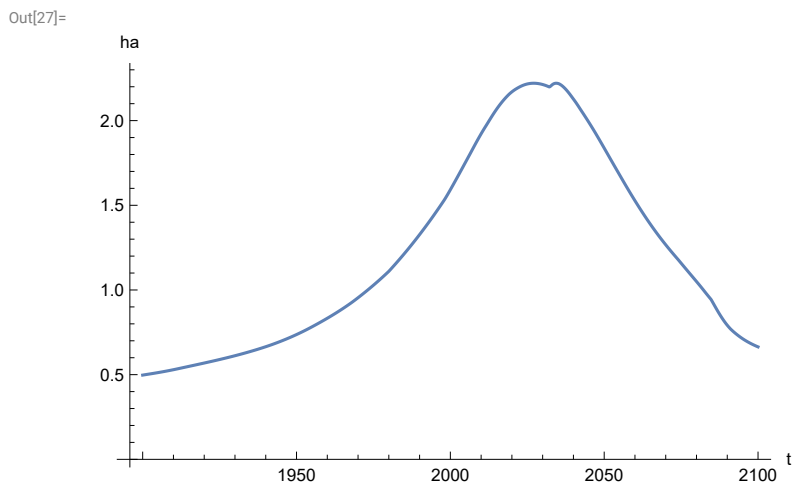
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

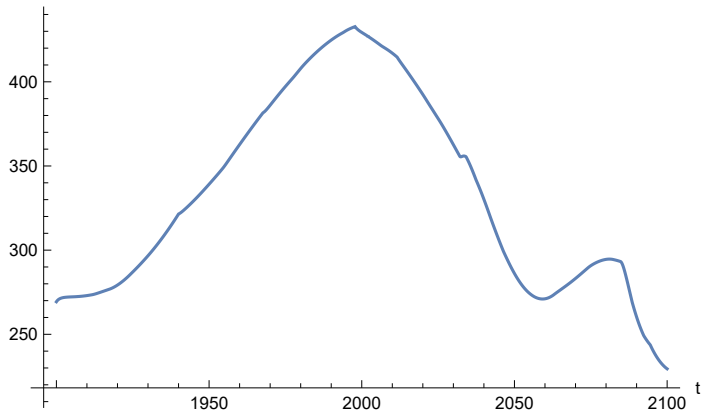
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

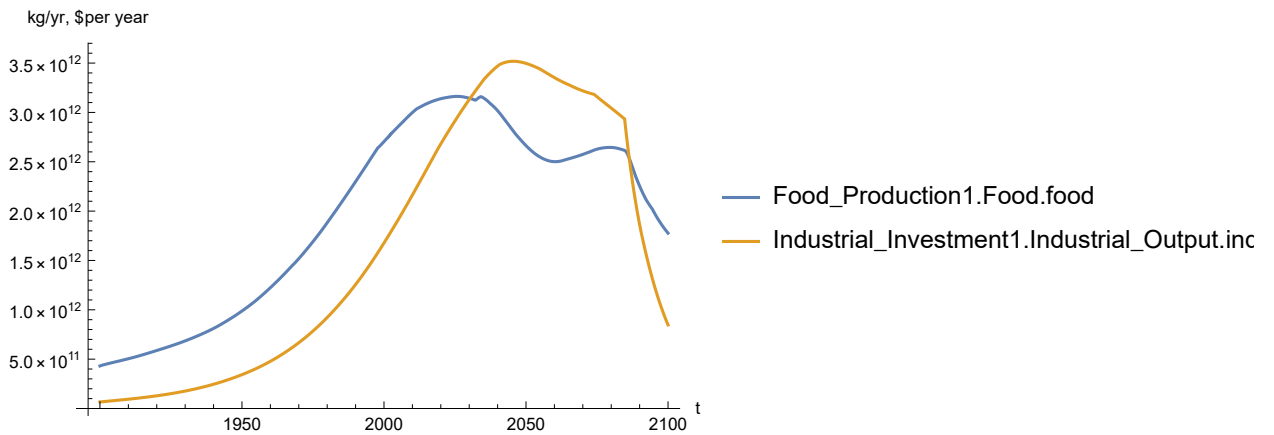
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

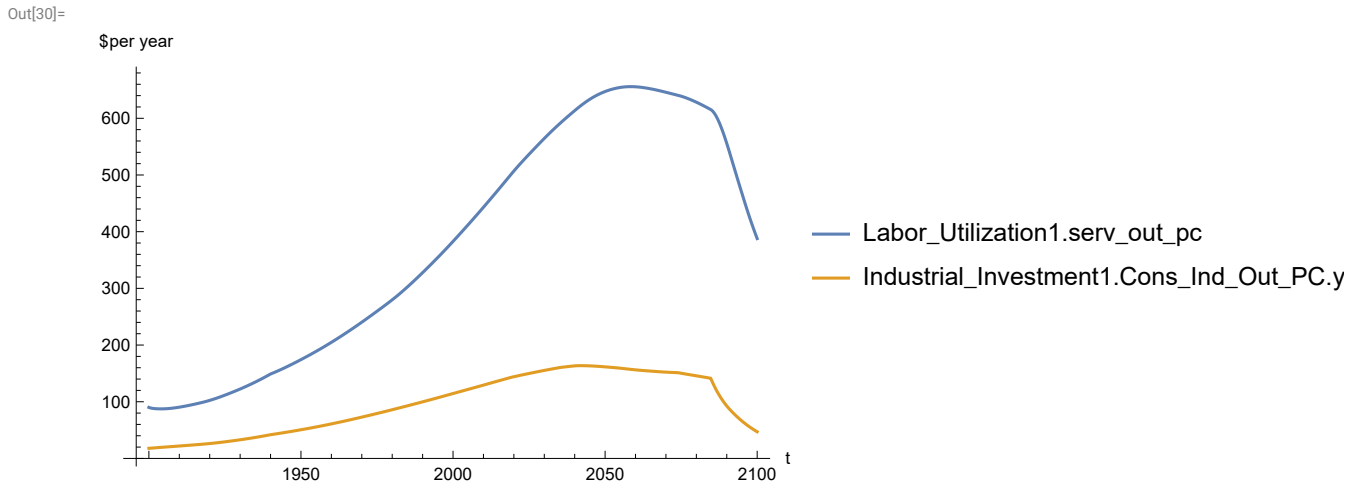
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

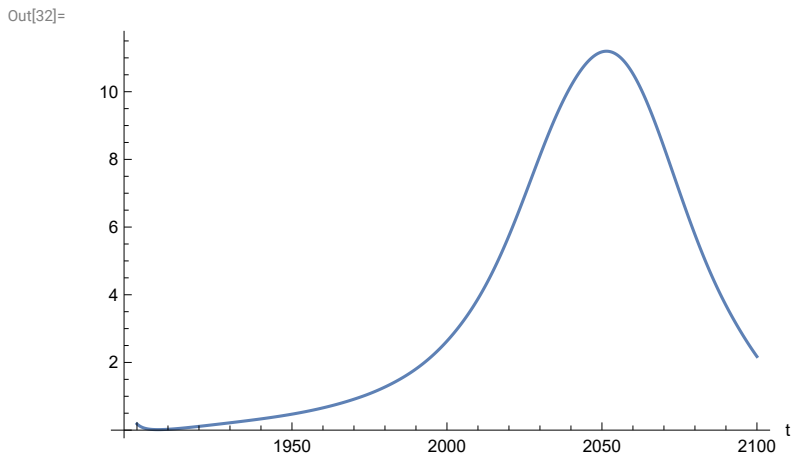


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 655.832
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



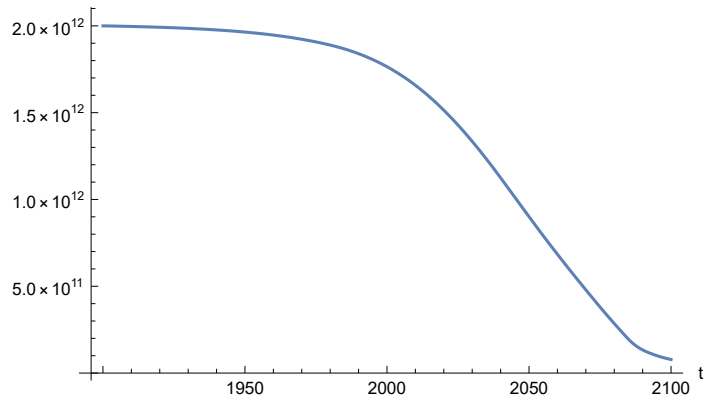
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.1964
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

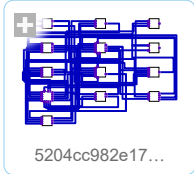
Out[34]=



APPENDIX 28. $t_policy_year = 1970$, Benchmark Scenario 3, Experiment 28

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.

```
In[35]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
Out[35]=
```



```
In[36]:= testsim1970 = SystemModelSimulate[newmysim1970]
Out[36]=
```

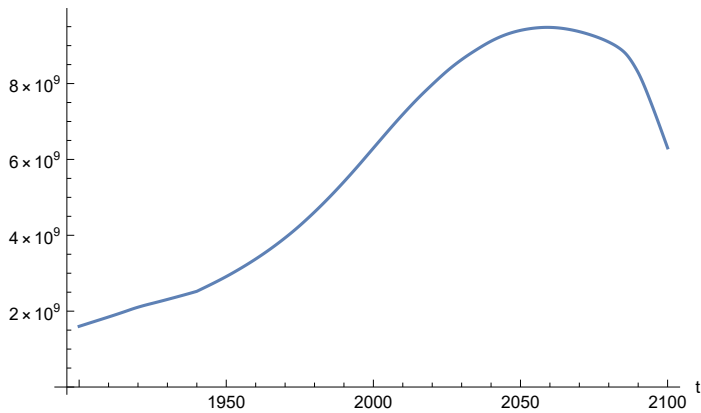
```
SystemModelSimulationData [  Model: W5204cc982e174ade9fc54dda98526f5  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of t_policy_year .

```
In[37]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
Out[37]=
{t_policy_year → 1970}
```

Plot the world population, people.

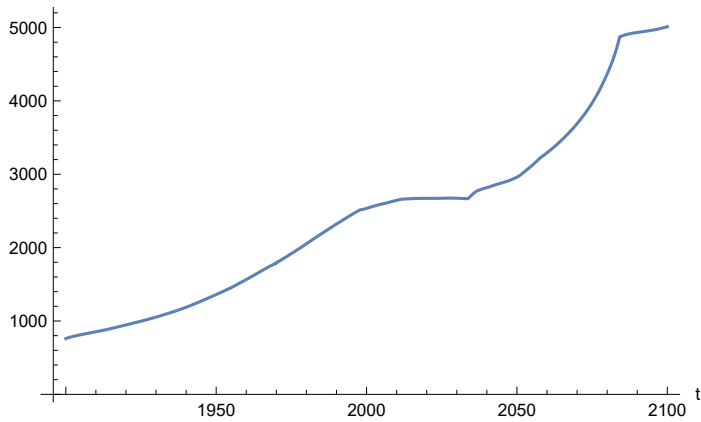
```
In[38]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[38]=
```



Find max and min of y values.

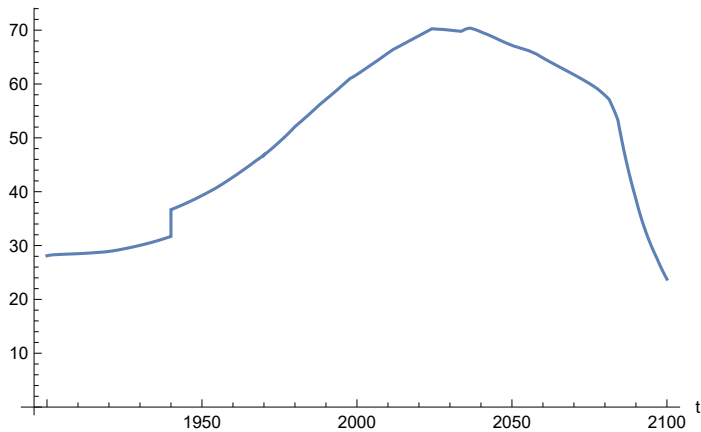
```
In[39]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.48139 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[40]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
Out[40]=
```



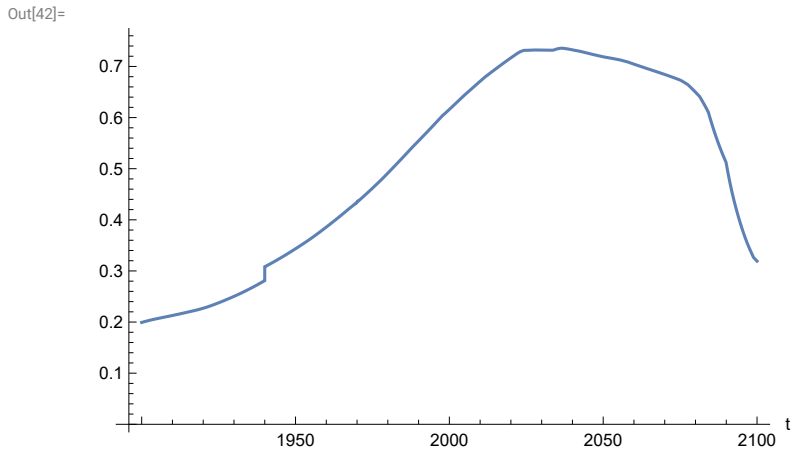
Plot life expectancy, in years.

```
In[41]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[41]=
```



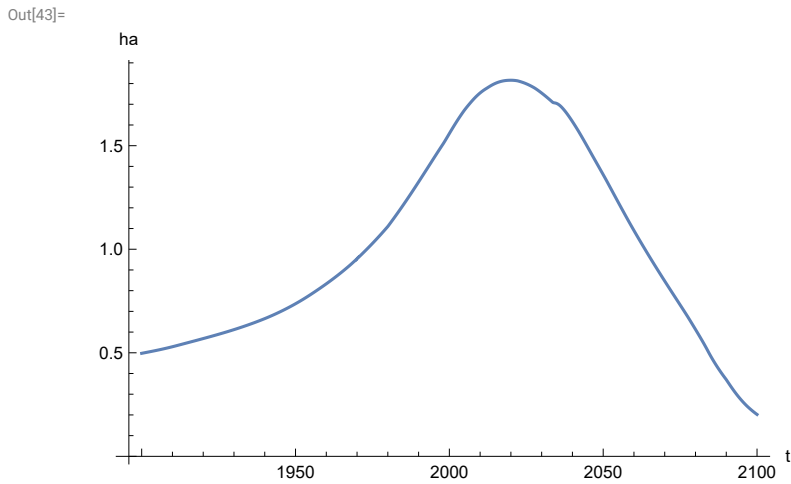
Plot the human welfare index.

```
In[42]:= SystemModelPlot[testsim1970,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



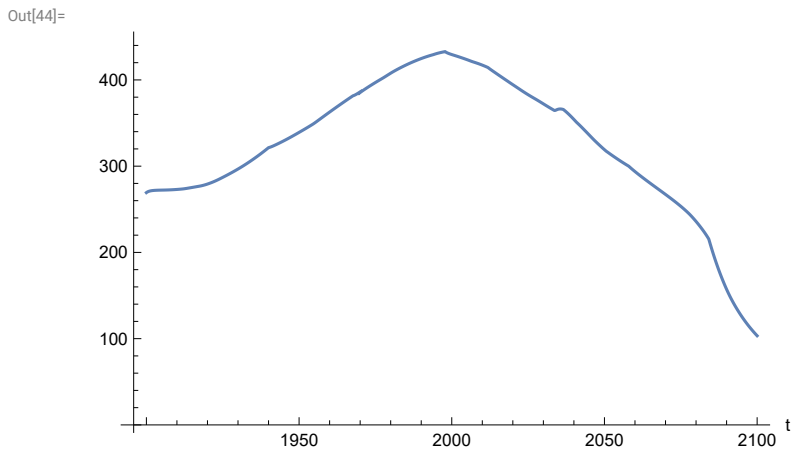
Plot the human ecological footprint, in hectares.

```
In[43]:= SystemModelPlot[testsim1970,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



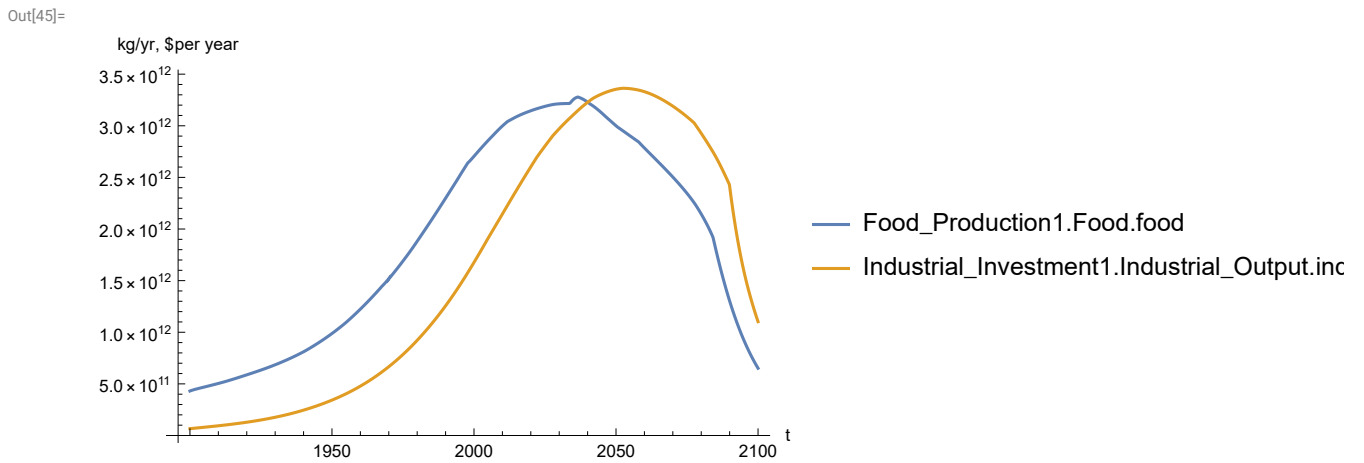
Plot per capita food production, kg/year.

```
In[44]:= SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]
```



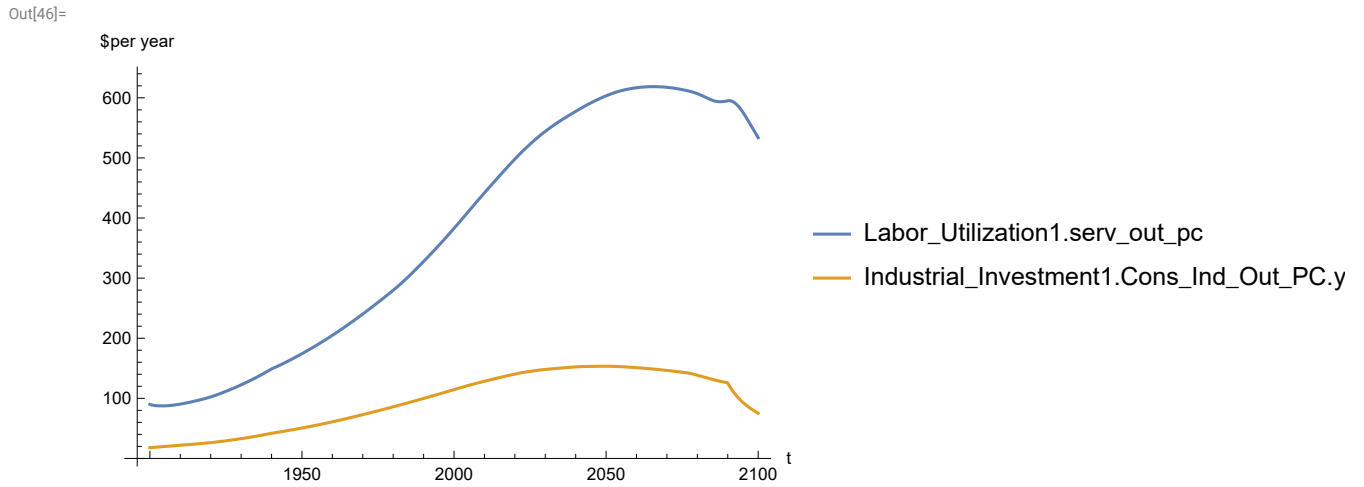
Plot total food production (kg/yr) and industrial output (in dollars).

```
In[45]:= SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[46]:= SystemModelPlot[testsim1970,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

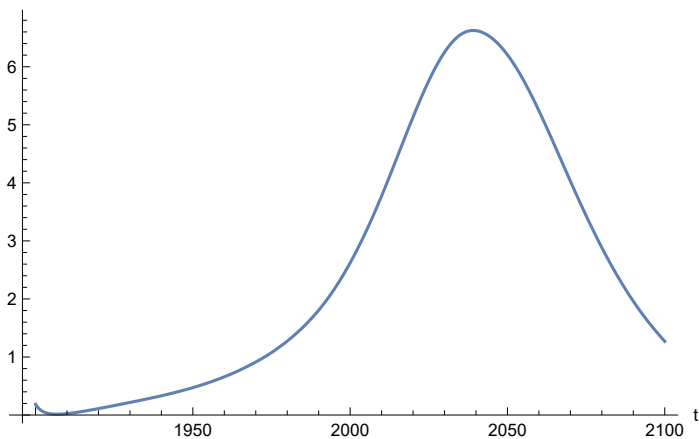


Find max and min of y values.

```
In[47]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 618.57
Minimum is 87.4451
```

Plot persistent pollution index (normalized to 1970 value).

```
In[48]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[48]=
```

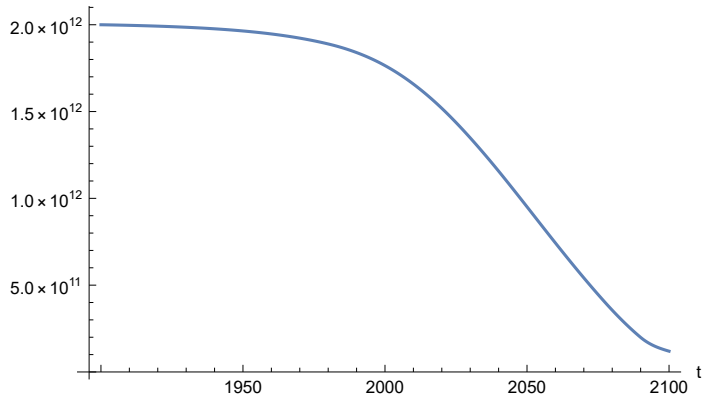


Find max and min of y values.

```
In[49]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 6.62485
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

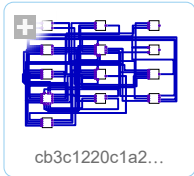
```
In[50]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[50]=
```




APPENDIX 29. Benchmark Scenario 3, `t_policy_year = 2025`. Experiment 29.

Change the value of `t_policy_year` 2025, and execute the resulting scenario, plotting various variables.

```
In[51]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[51]=
```



```
In[52]:= testsim = SystemModelSimulate[newmysim]
Out[52]=
```

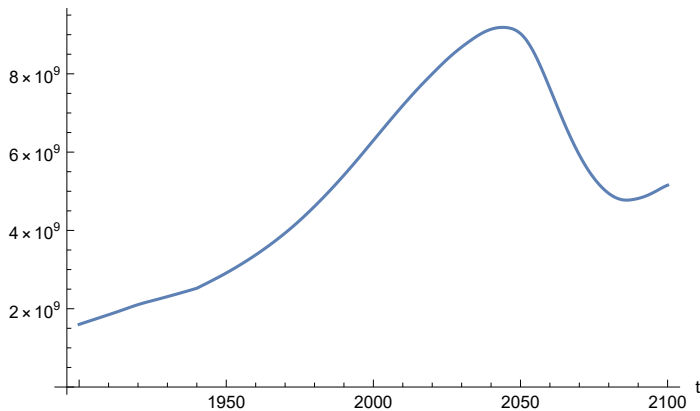
```
SystemModelSimulationData [  Model: Wcb3c1220c1a243d581625c2920021b4d  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of `t_policy_year`.

```
In[53]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
Out[53]= {t_policy_year → 2025}
```

Plot the world population, people.

```
In[54]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[54]=
```

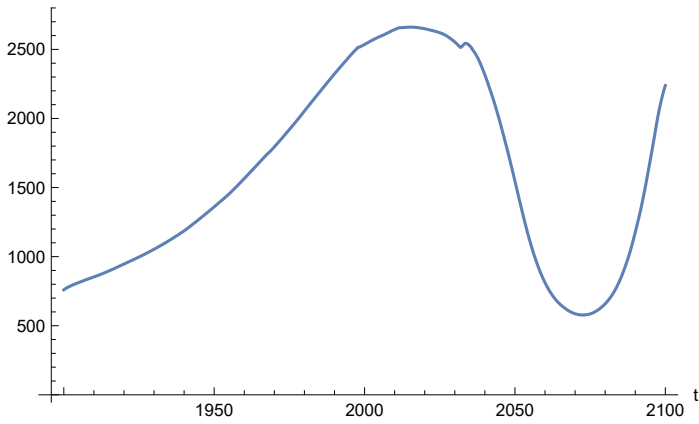


Find max and min of y values.

```
In[55]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.18674 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

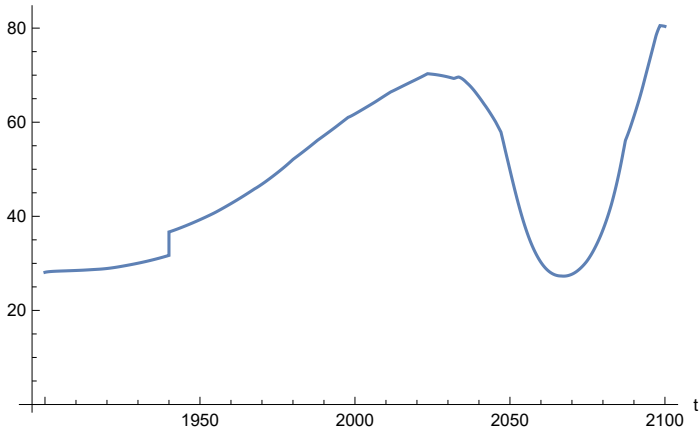
Plot land yield.

```
In[56]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[56]=
```



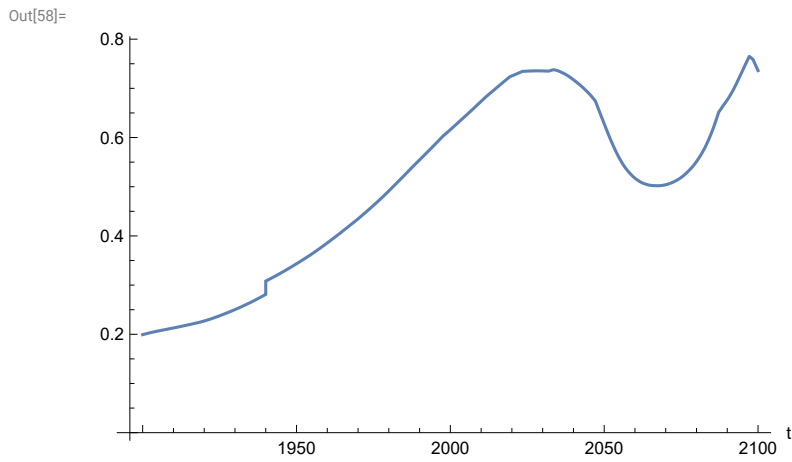
Plot life expectancy, in years.

```
In[57]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[57]=
```



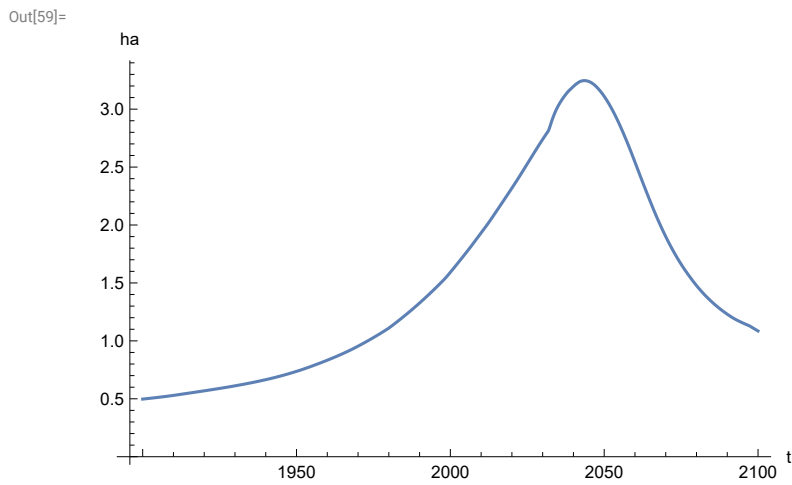
Plot the human welfare index.

```
In[58]:= SystemModelPlot[testsim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



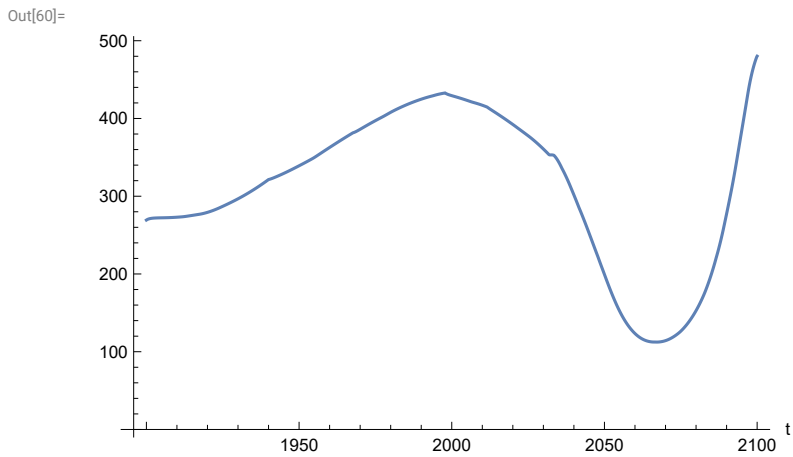
Plot the human ecological footprint, in hectares.

```
In[59]:= SystemModelPlot[testsim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



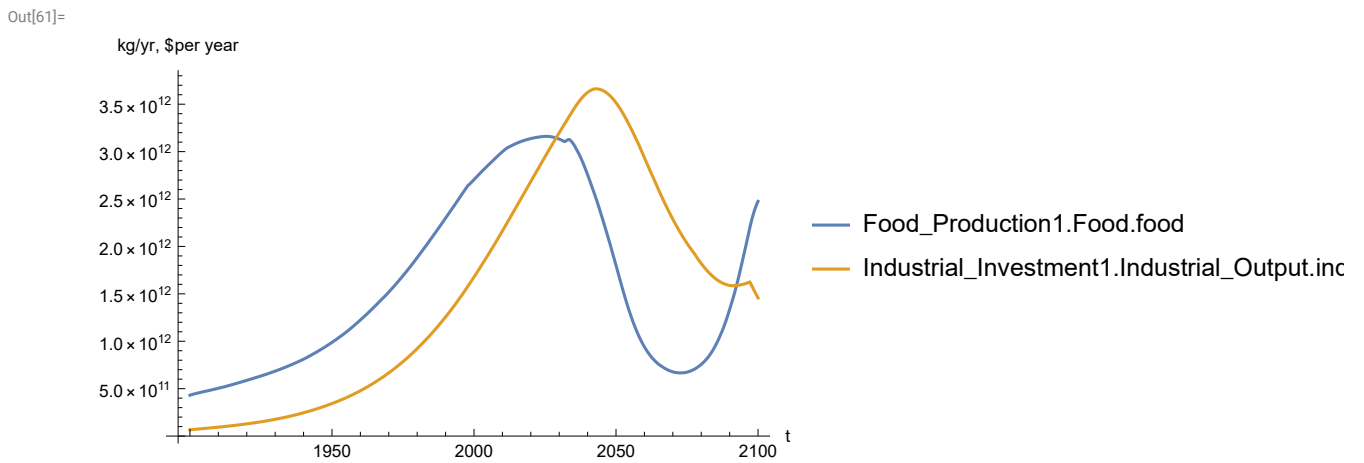
Plot per capita food production, kg/year.

```
In[60]:= SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]
```



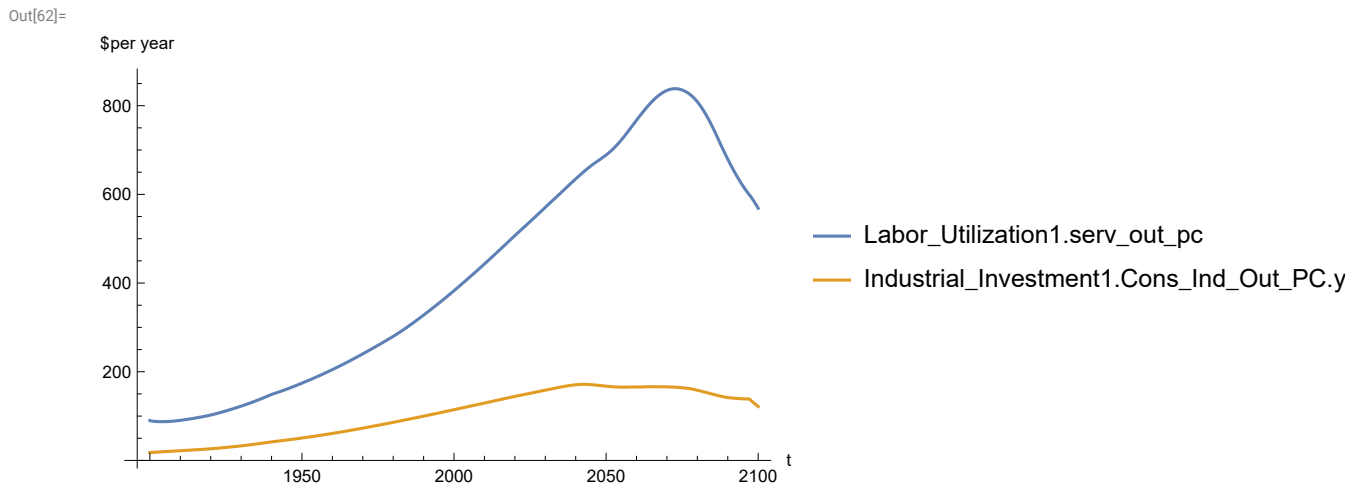
Plot total food production (kg/yr) and industrial output (in dollars).

```
In[61]:= SystemModelPlot[testsim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot consolidated industrial output per capita (dollars/year).

```
In[62]:= SystemModelPlot[testsim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

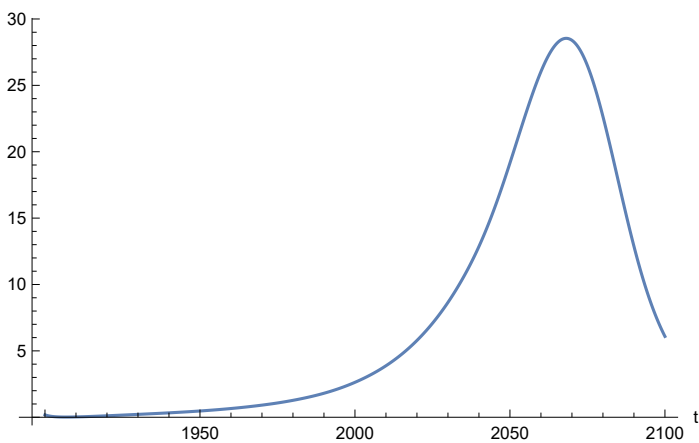


Find max and min of y values.

```
In[63]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 838.424
Minimum is 87.4451
```

Plot persistent pollution index (normalized to 1970 value).

```
In[64]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[64]=
```

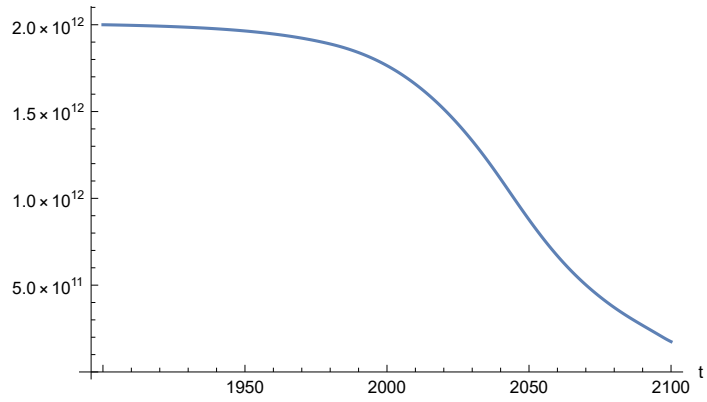


Find max and min of y values.

```
In[65]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 28.5415
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[66]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[66]=
```



APPENDIX 30. BENCHMARK SCENARIO 3, Experiment 30. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 23 July 2022/1350 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

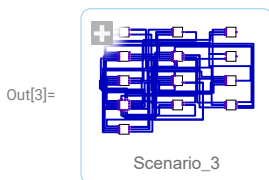
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

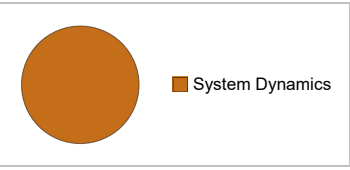
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 3.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_3"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_3
	Description	More accessible non-recoverable natural resources and pollution control
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	Simulation Length	265
	Simulation Length	265
	Description	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

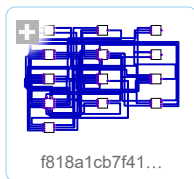
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

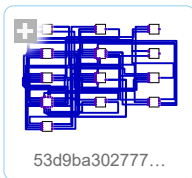
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

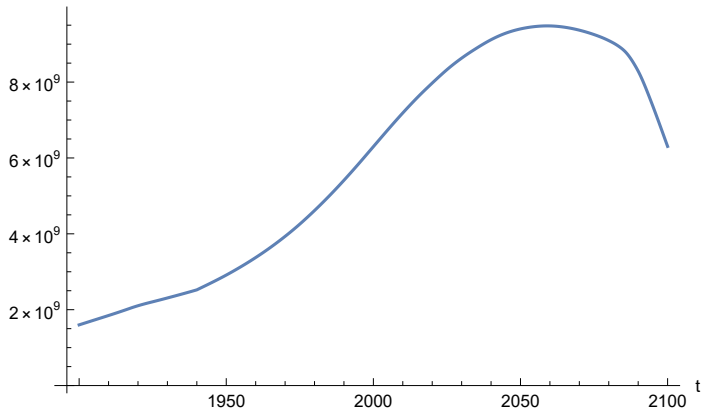
```
Out[21]=
```

```
SystemModelSimulationData [   Model: W53d9ba30277745469a1fc9fcd6aa4919
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

Out[22]=



Find max and min of population values.

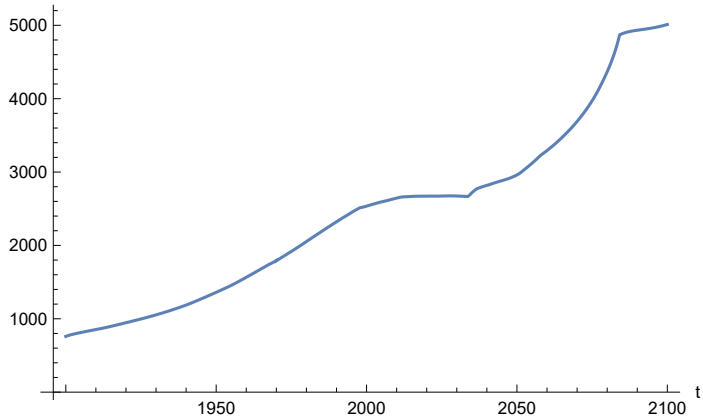
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 9.48139×10^9

Minimum is 1.6×10^9

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

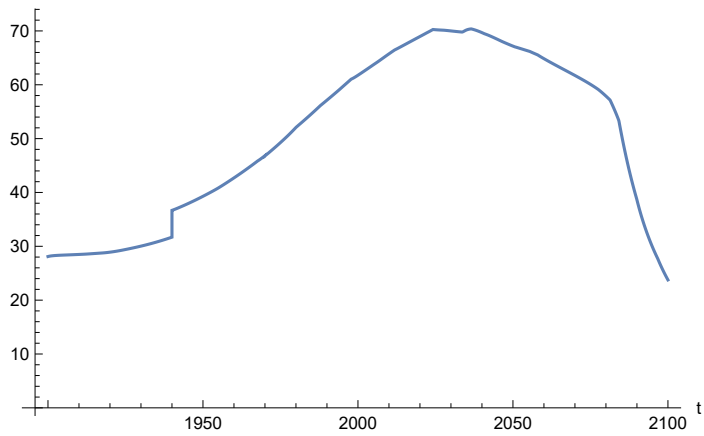
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[25]=

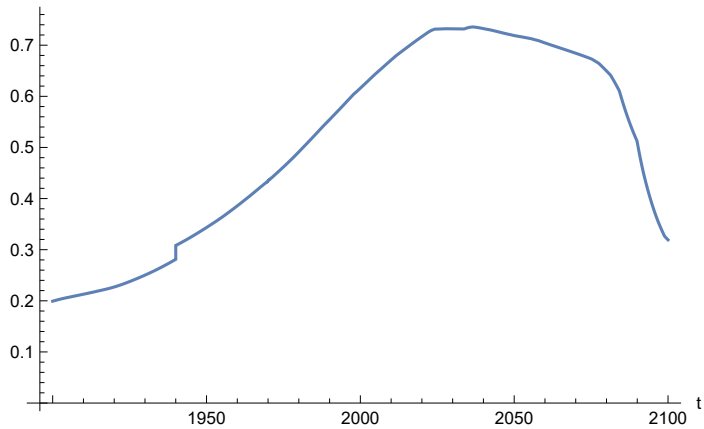


```
In[26]:=
```

Plot human welfare index.

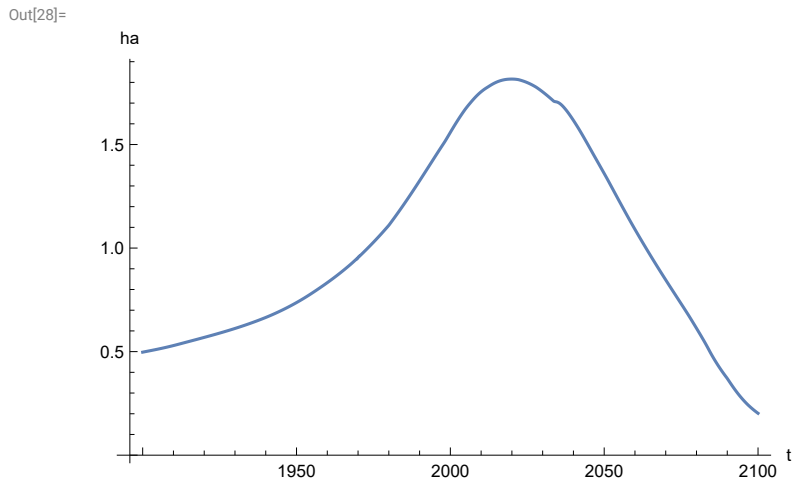
```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

Out[27]=



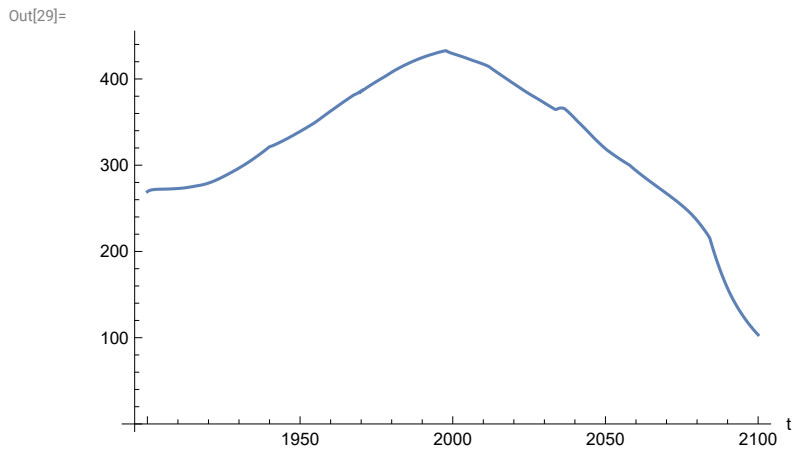
Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

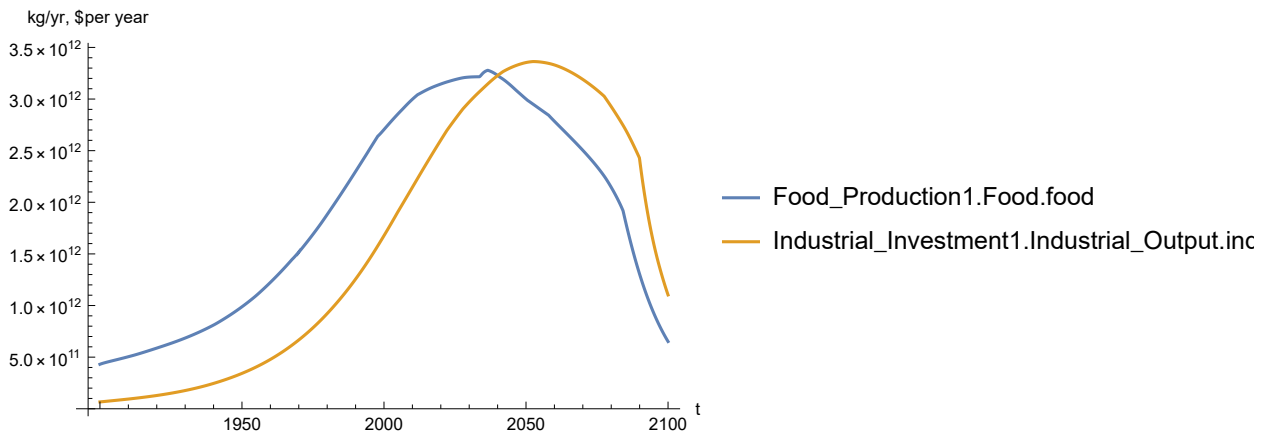
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

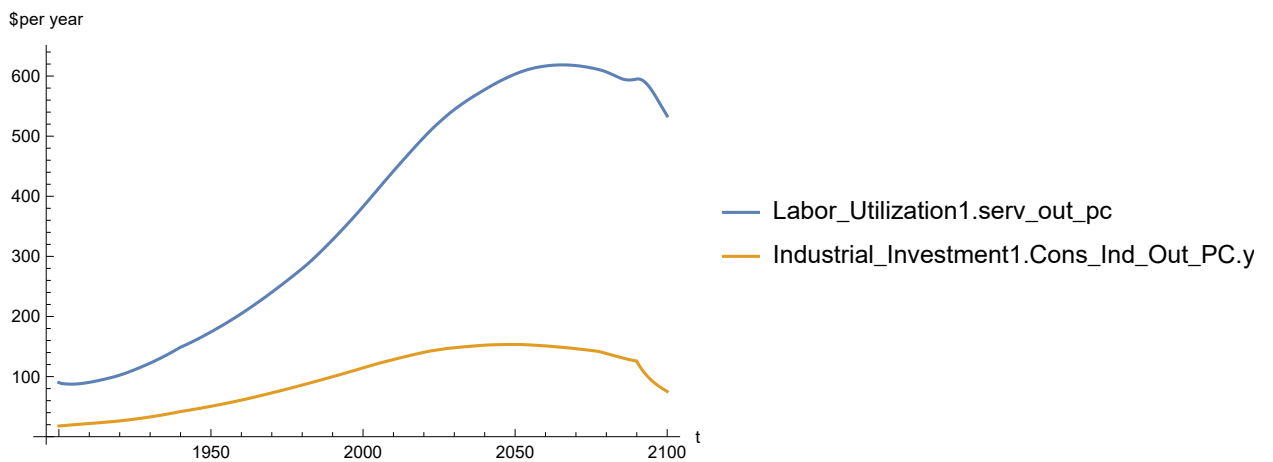
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim, {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

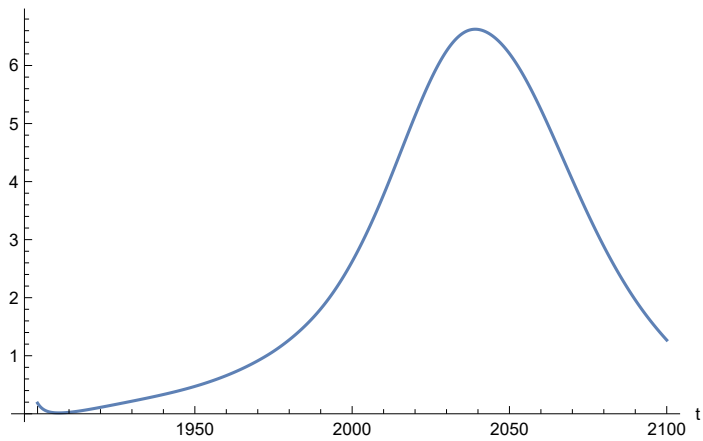
```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 618.57
 Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

```
Out[33]=
```



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

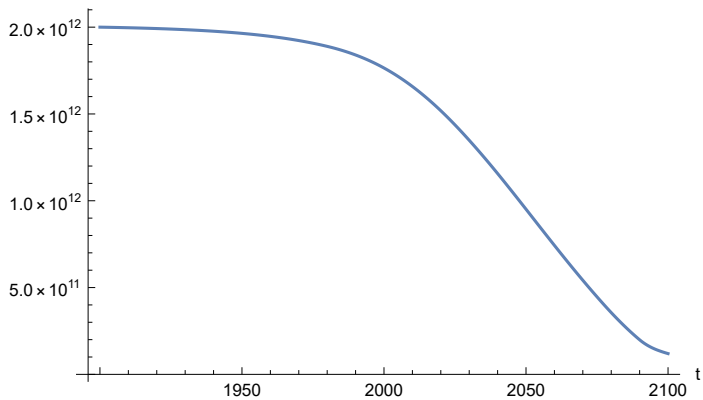
```
Maximum is 6.62485
```

```
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

```
Out[35]=
```

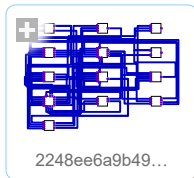


APPENDIX 31. LE/1.001, t_policy_year = 2025. Baseline Scenario 3, Experiment 31.

Set `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals` to LE/1.001. Note: this particular divisor does not change the two-significant-figure default `_Serv_2.y_vals`

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[36]=



Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals`.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

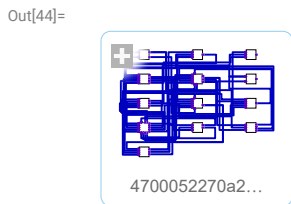
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```



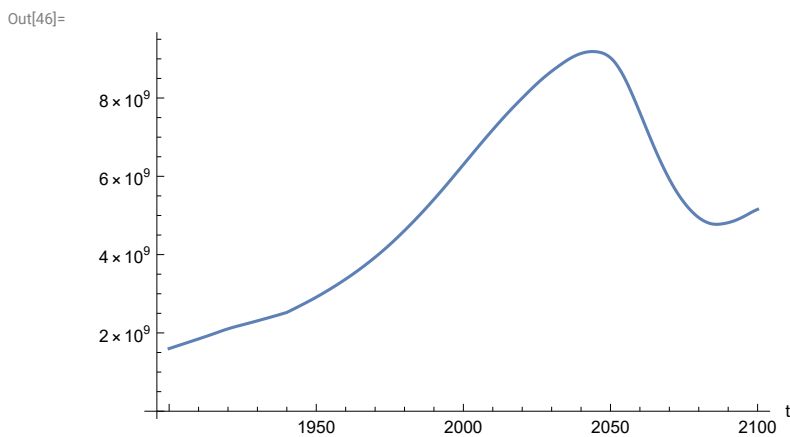
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W4700052270a24f93be90f189d20d5223
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

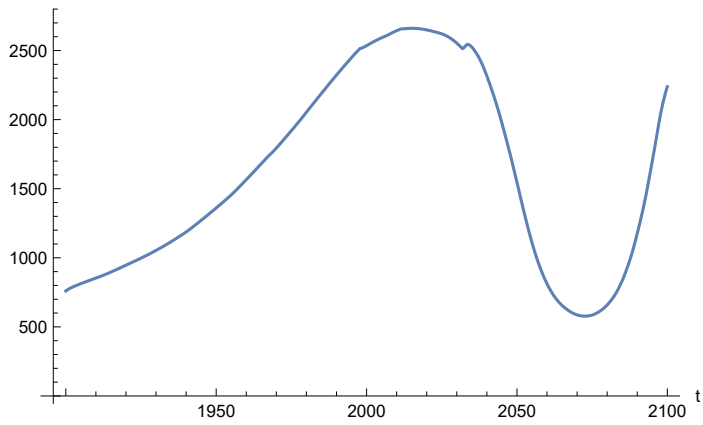
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 9.18674×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

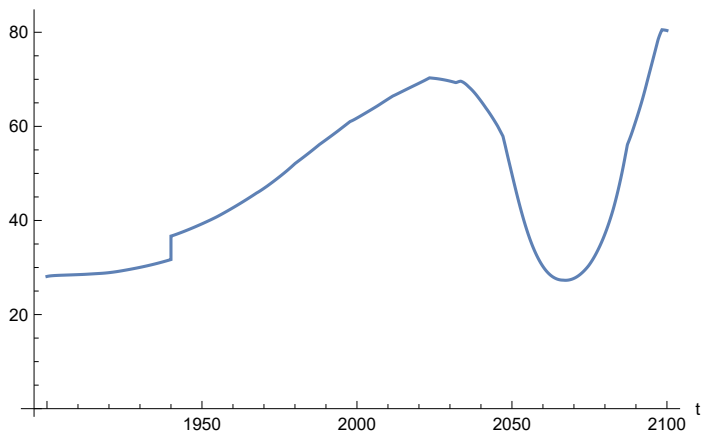
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

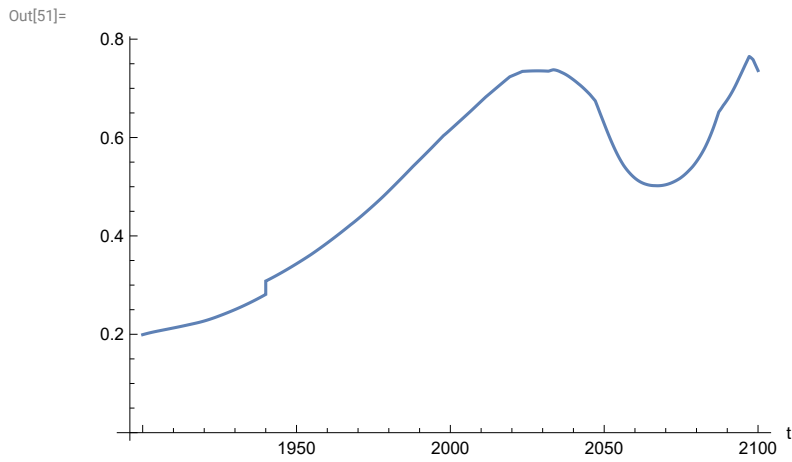
Out[49]=



In[50]:=

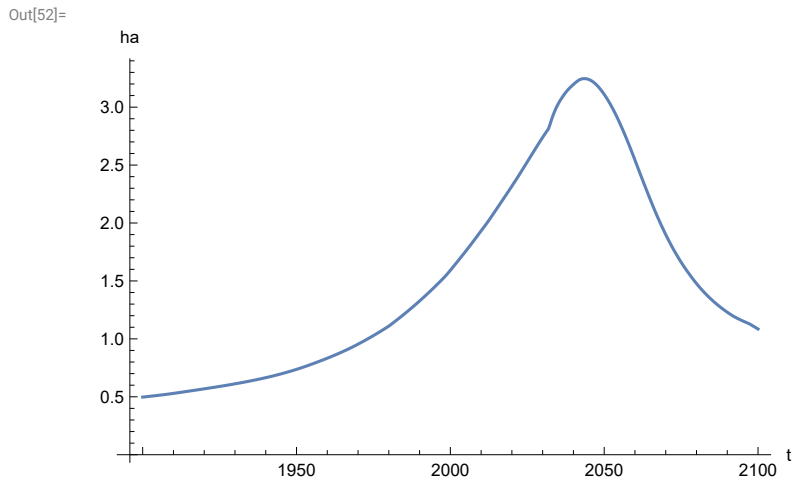
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[52]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



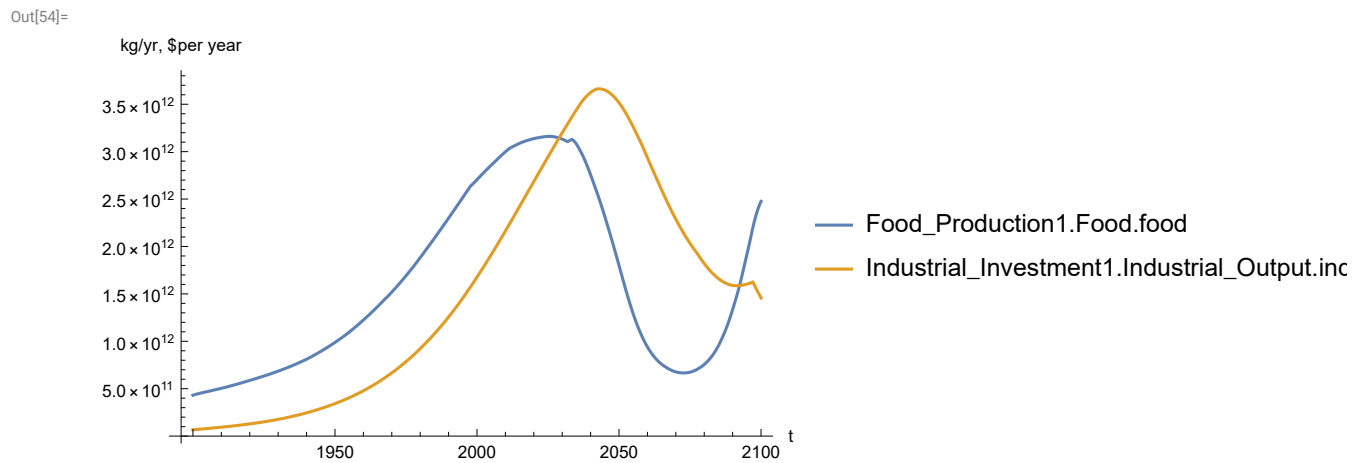
Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]



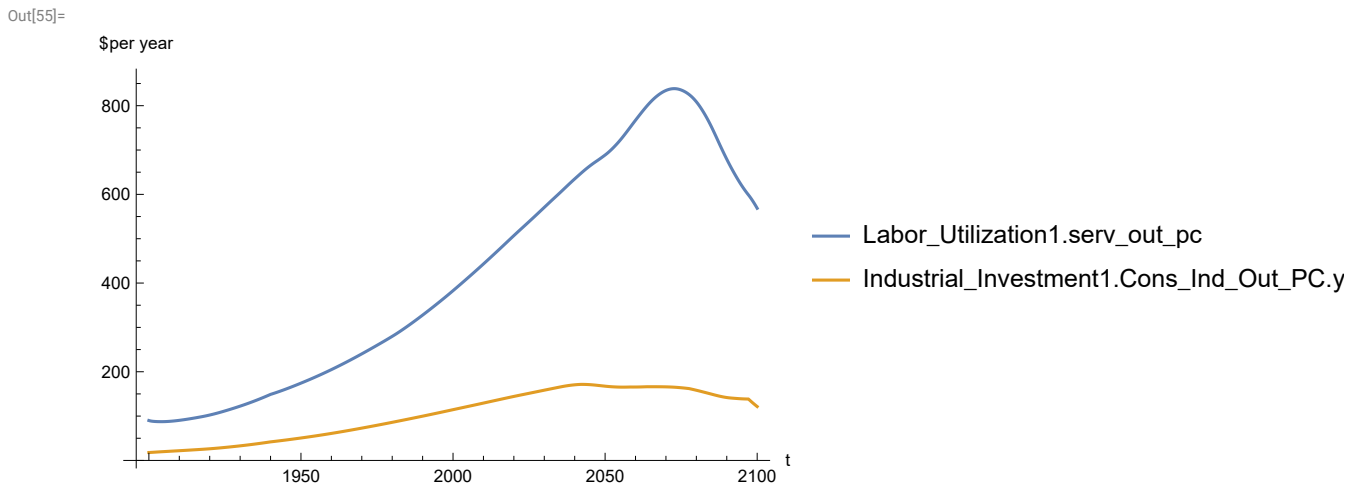
Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

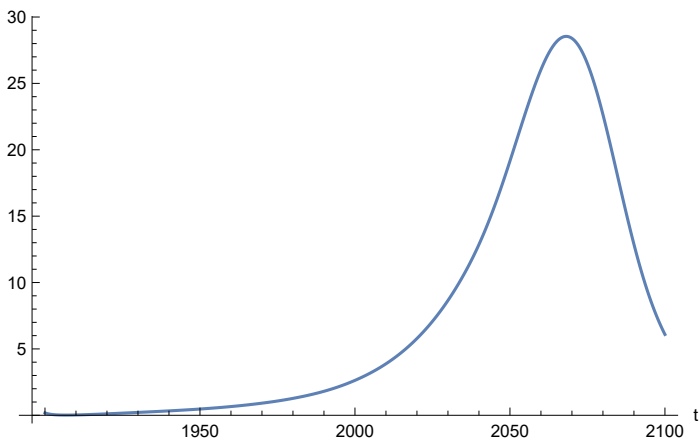


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 838.424
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



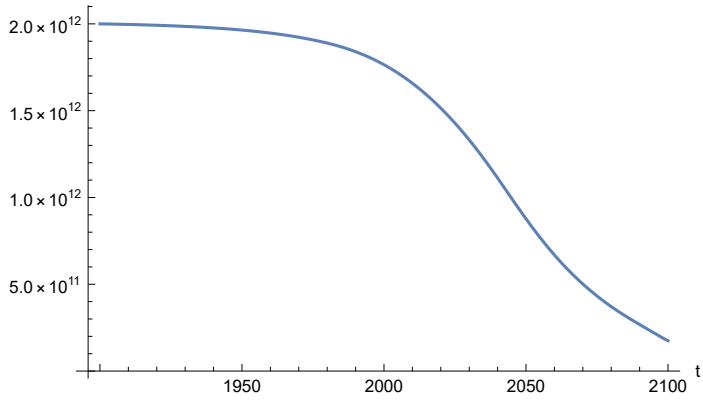
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 28.5415
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

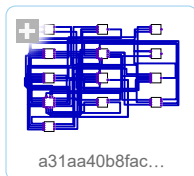


APPENDIX 32. LE/1.01, t_policy_year = 1970. Baseline Scenario 3, Experiment 32.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

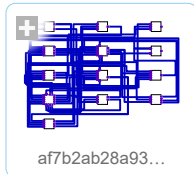
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

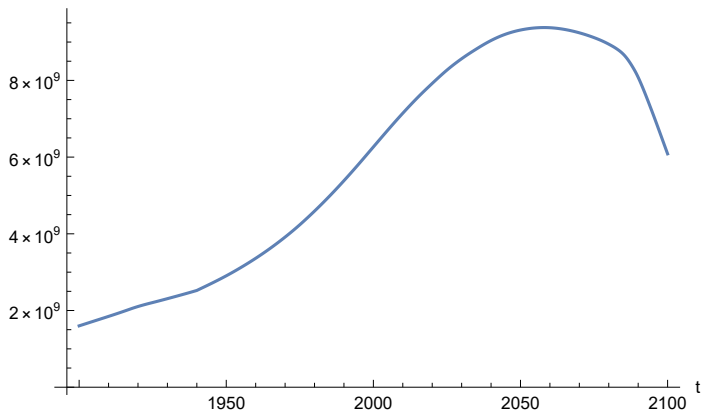
```
Out[69]=
```

```
SystemModelSimulationData [ {  Model: Waf7b2ab28a934cc89f10e51fbf36ffb4  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  } ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

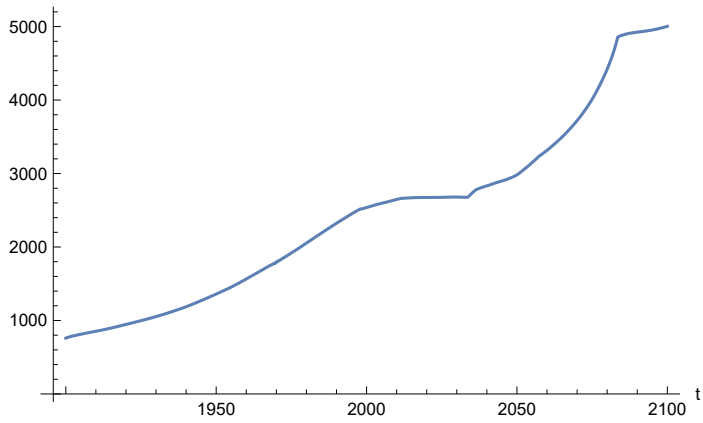
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.37804 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

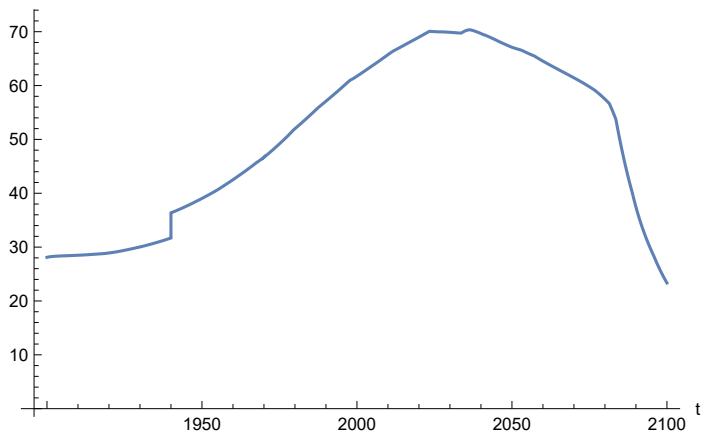
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

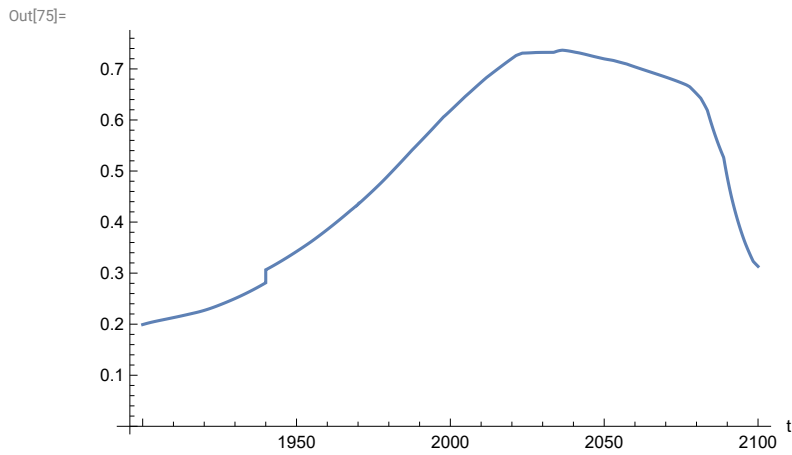
Out[73]=



In[74]:=

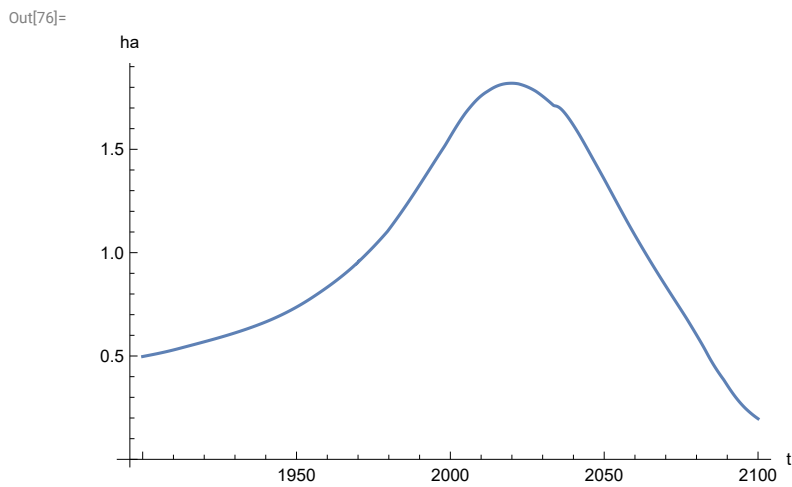
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



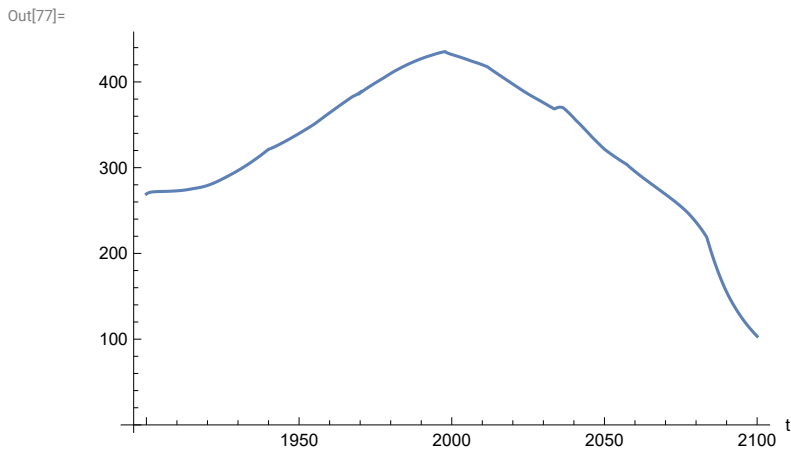
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



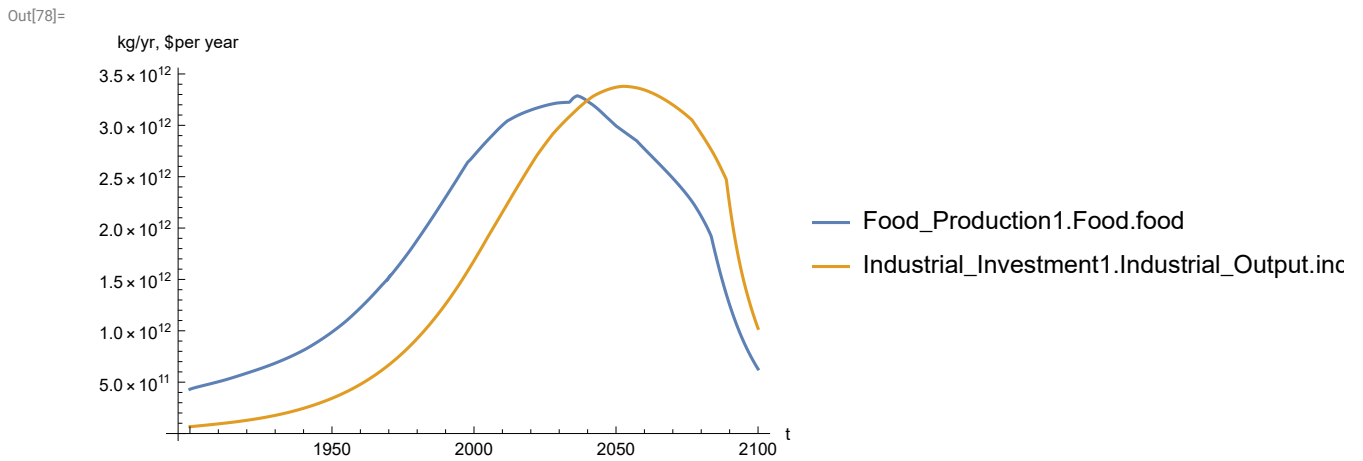
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

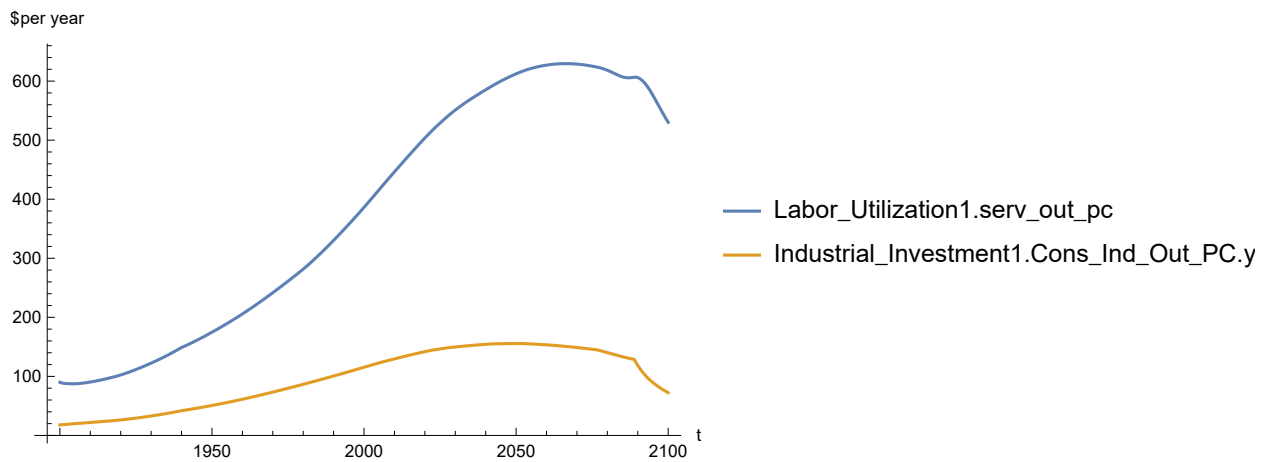
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

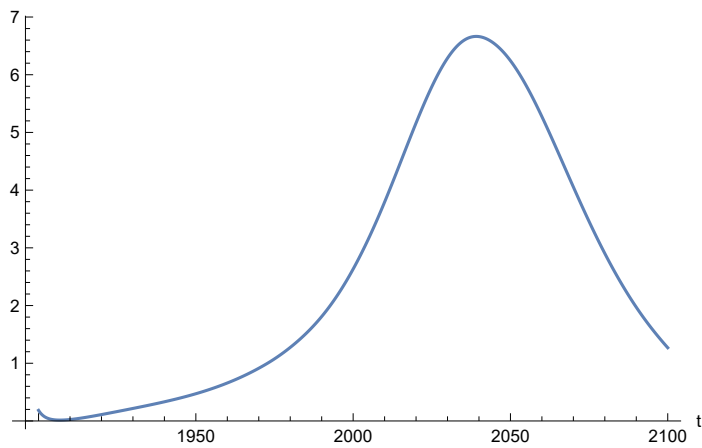
Maximum is 629.571

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

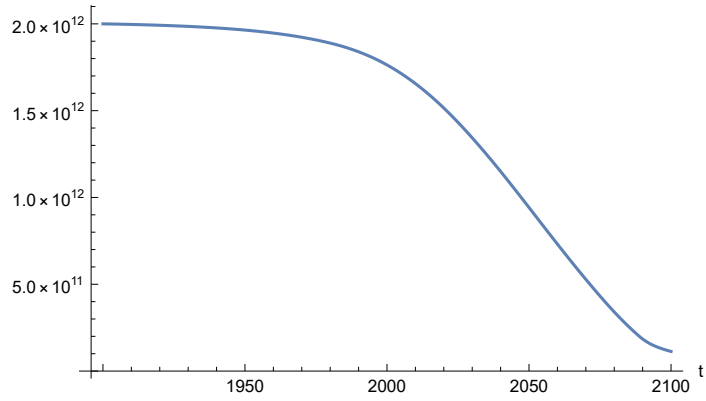
Maximum is 6.66395

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

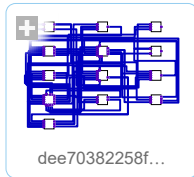
Out[83]=



APPENDIX 33. Baseline Scenario 3, Experiment 33. $LE = LE/1.01$, $t_policy_year = 2025$.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

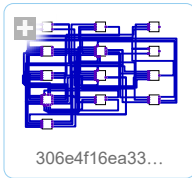
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 2025.


```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

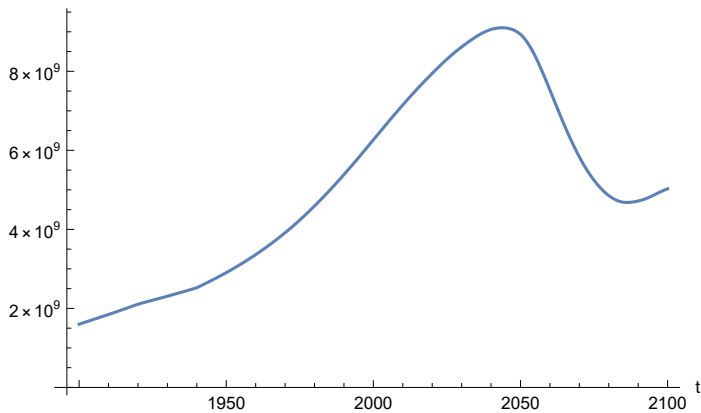
```
Out[93]=
```

```
SystemModelSimulationData [   Model: W306e4f16ea33491e8ce08b9d9637e47e  
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[94]=
```



Find max and min of population values.

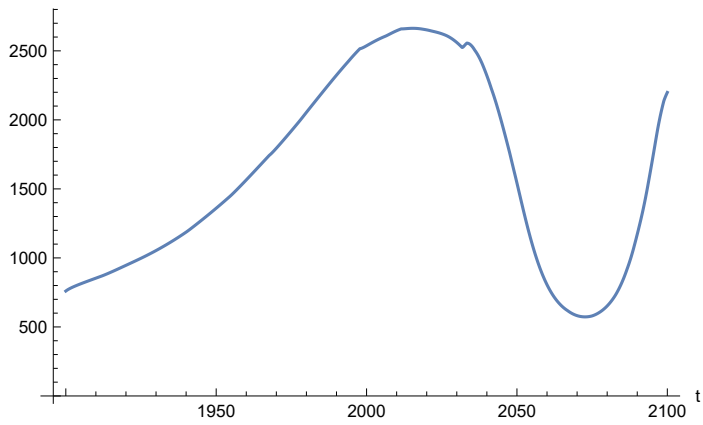
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.10171 × 109
```

```
Minimum is 1.6 × 109
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

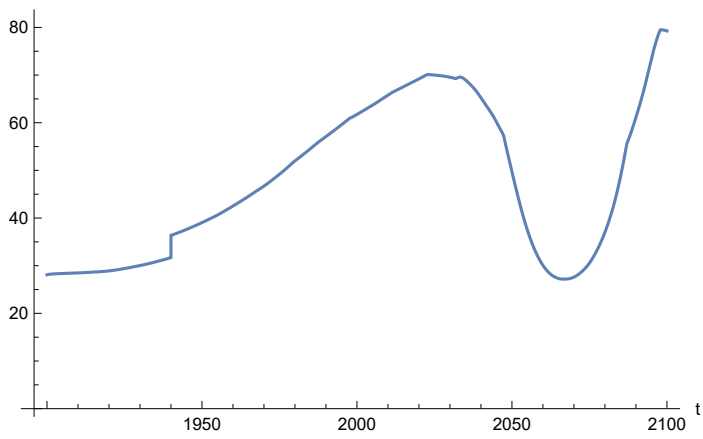
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

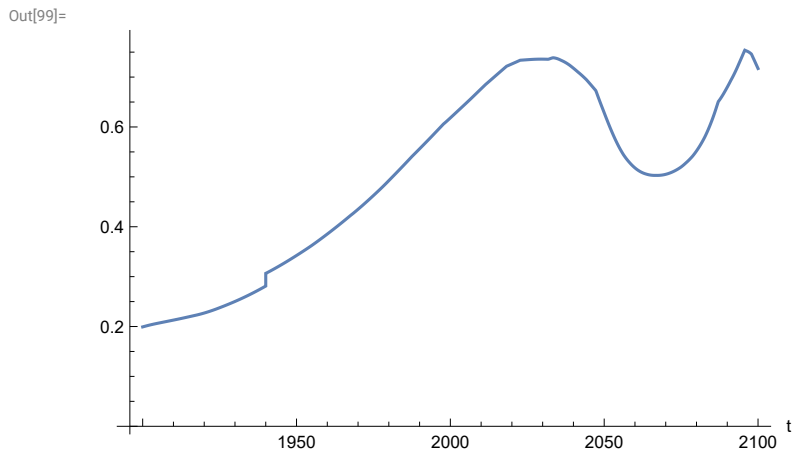
Out[97]=



In[98]:=

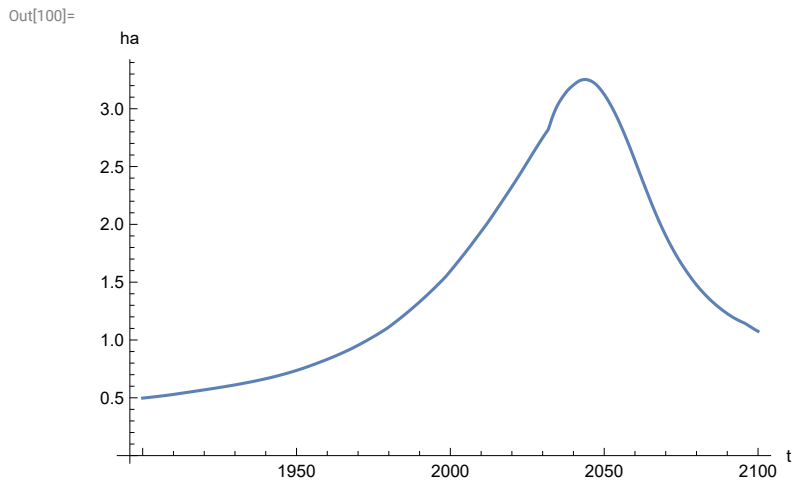
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

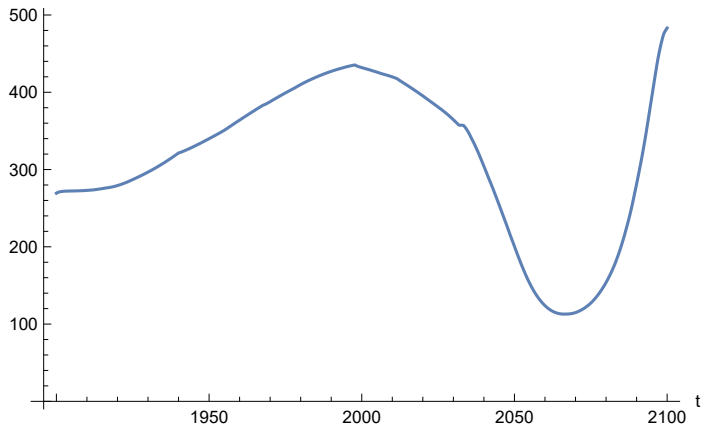


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

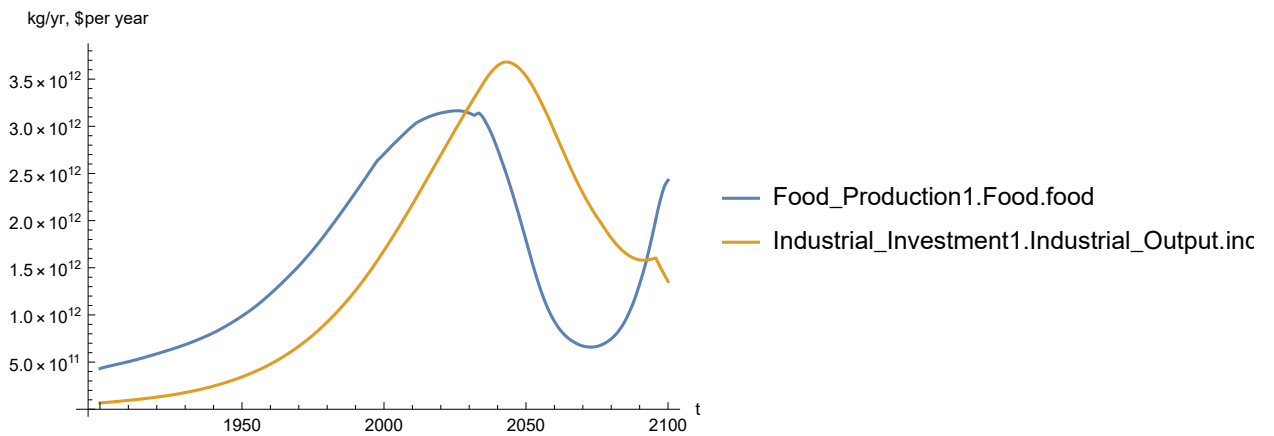


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

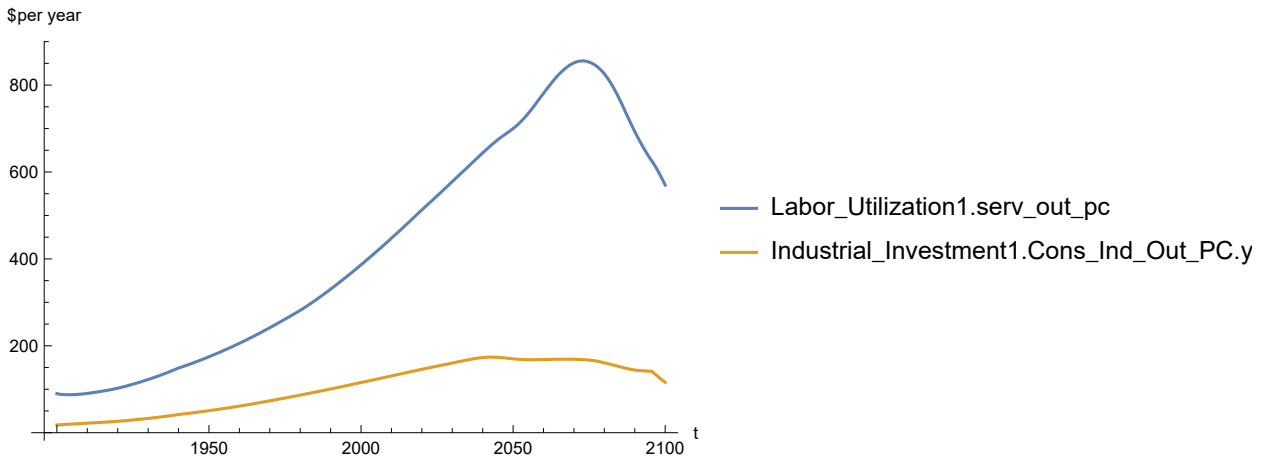


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

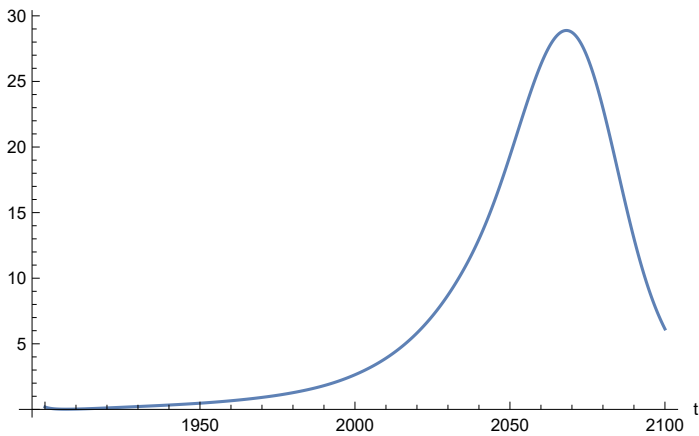
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 855.623
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 28.8844

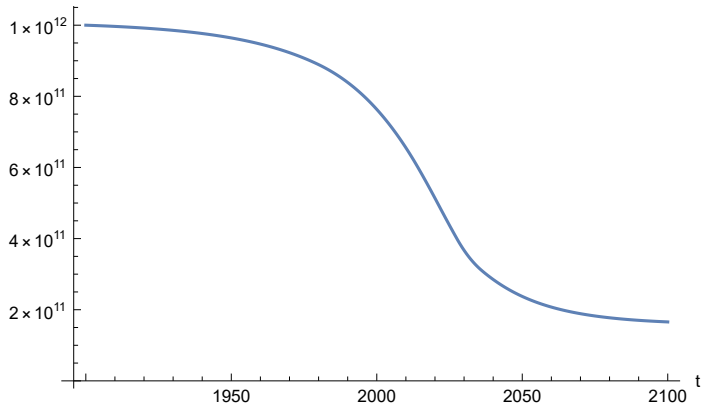
Minimum is 0.0150765

Plot non-renewable resources remaining.

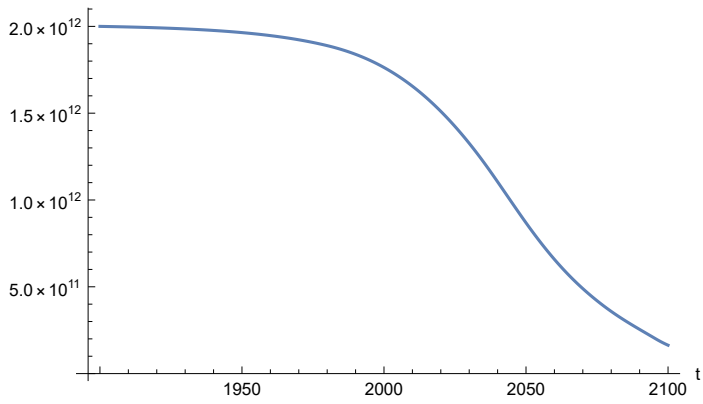
In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[107]=



Out[107]=



**APPENDIX 34. BENCHMARK SCENARIO 3, Experiment 34. $LE = LE/1.03$, $t_{policy_year} = 1970$.
Last modified: 28 July 2022/1110 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

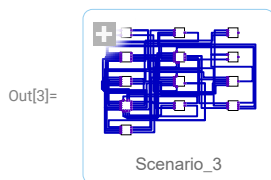
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

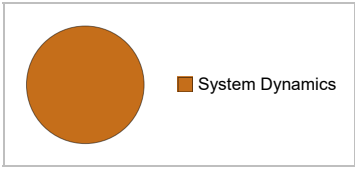
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 3.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_3"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_3
	Description	More accessible non-recoverable natural resources and pollution control
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	Simulation Years	265
	Simulation Years	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

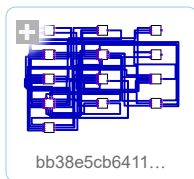
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

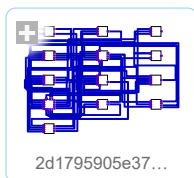
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

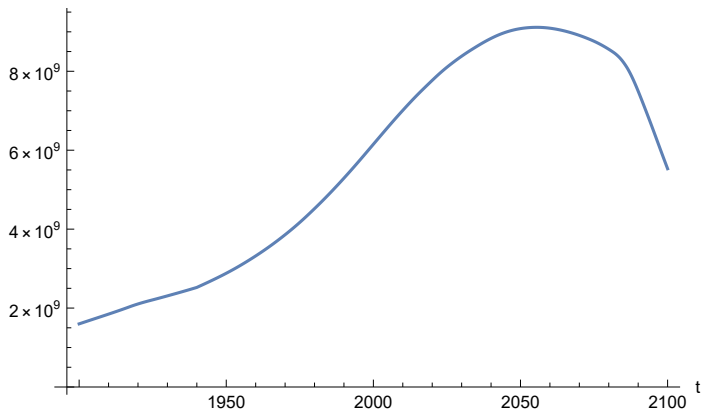
```
Out[21]=
```

```
SystemModelSimulationData [
  {
    Model: W2d1795905e3744479b6e15909ea0ef16
    Time: 1.90 × 103 to 2.10 × 103
  }
]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

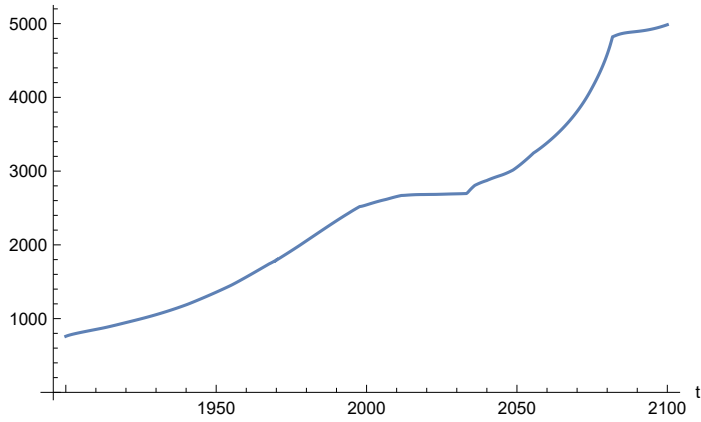
```
Out[22]=
```



Find max and min of population values.

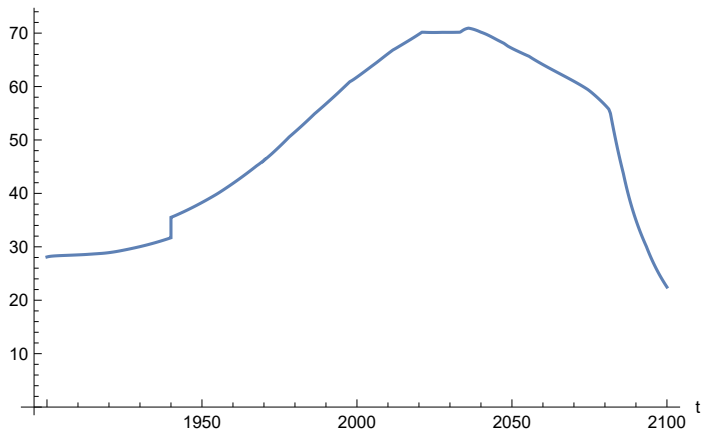
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.11374 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```

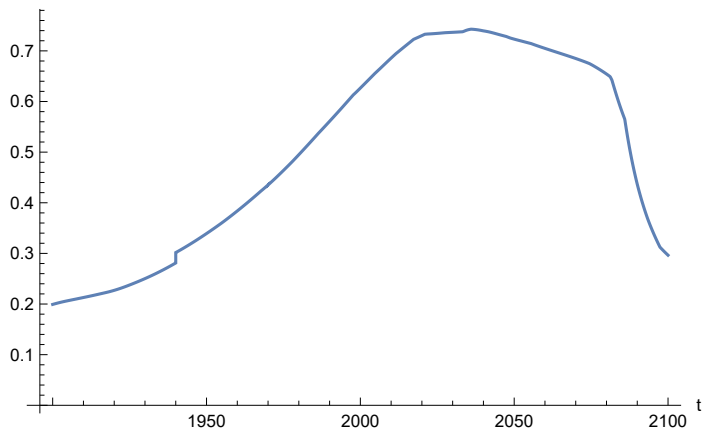


```
In[26]:=
```

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

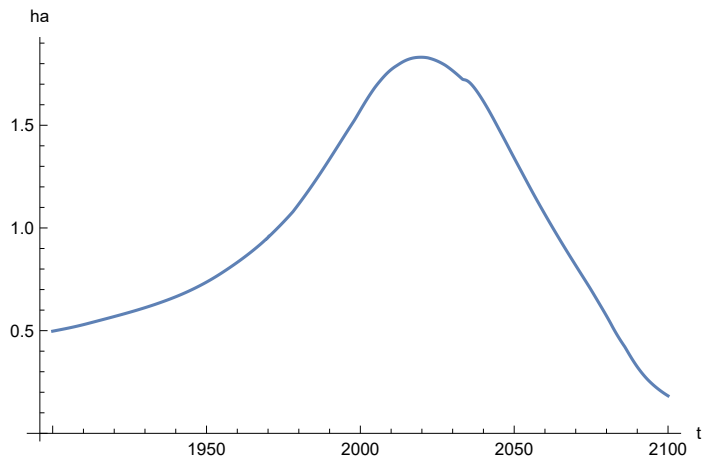
Out[27]=



Plot per capita ecological footprint, hectares.

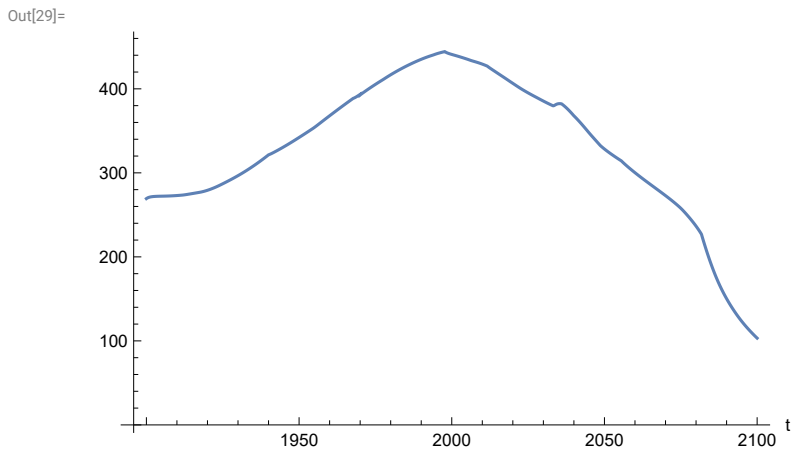
```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```

Out[28]=



Plot food production per capita (kg/year).

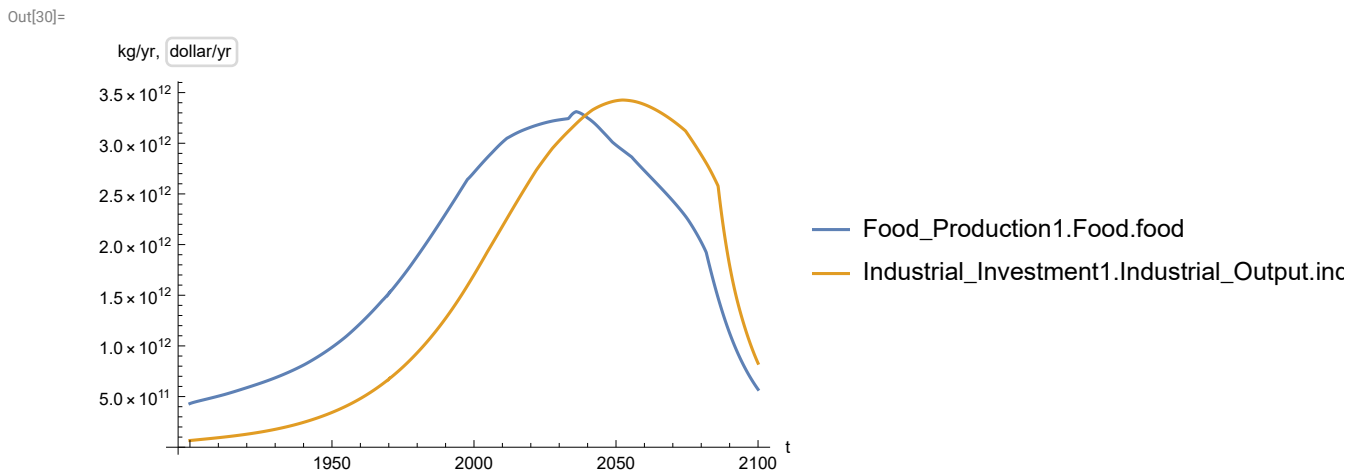
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

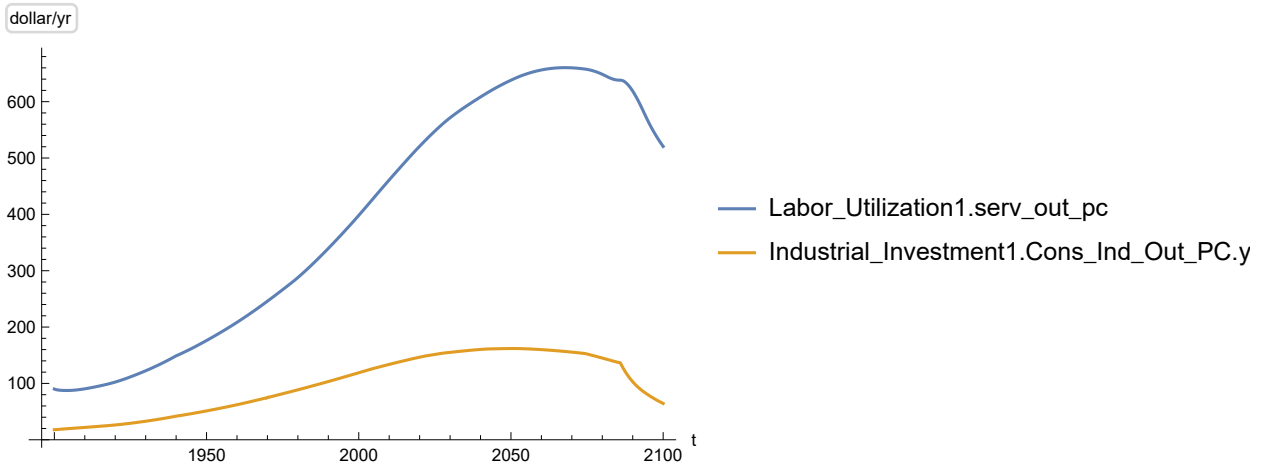
Quantity: A network operation for Quantity timed out. Please try again later.



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

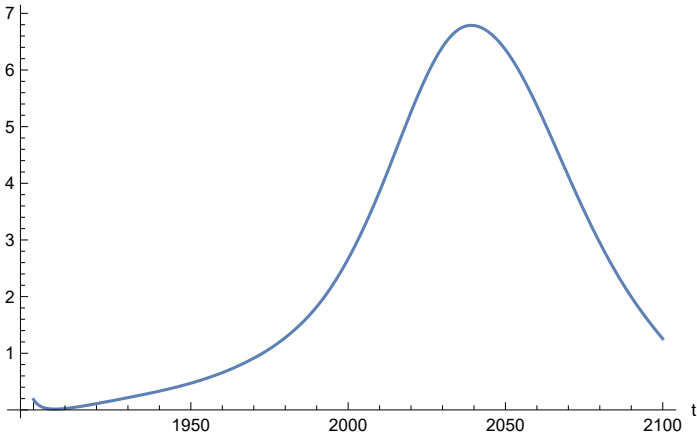
Maximum is 660.349

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

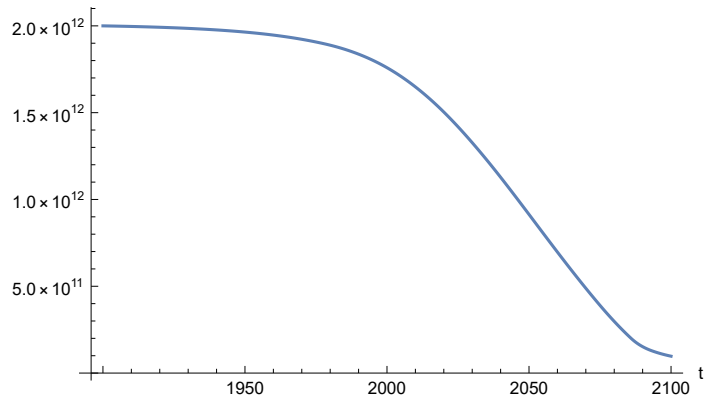
Maximum is 6.78789

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

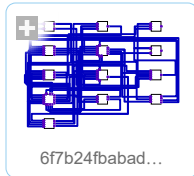


APPENDIX 35. LE/1.03, t_policy_year = 2025. Baseline Scenario 3, Experiment 35.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

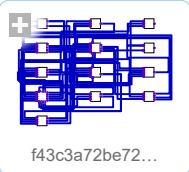
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

Out[44]=  f43c3a72be72...

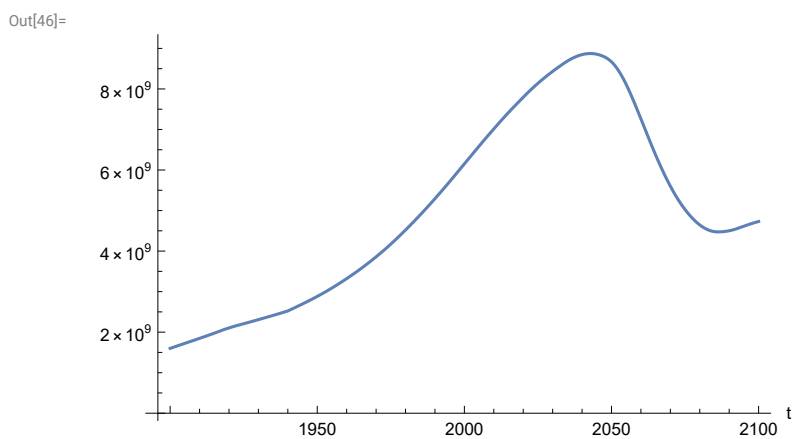
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: Wf43c3a72be7241de8430f8645fd30ded
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

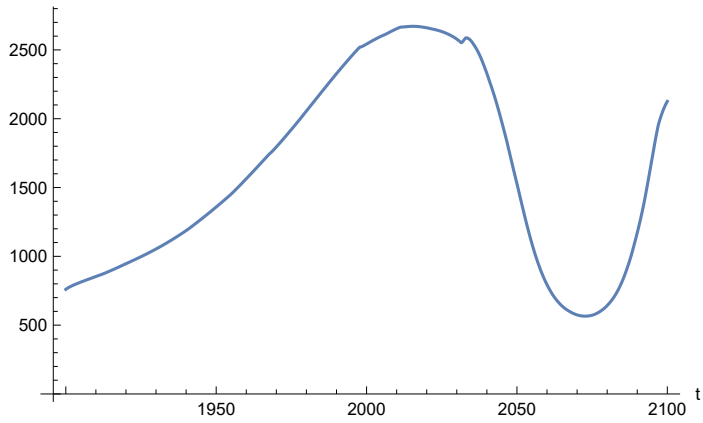
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.87326×10^9

Minimum is 1.6×10^9

In[48]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

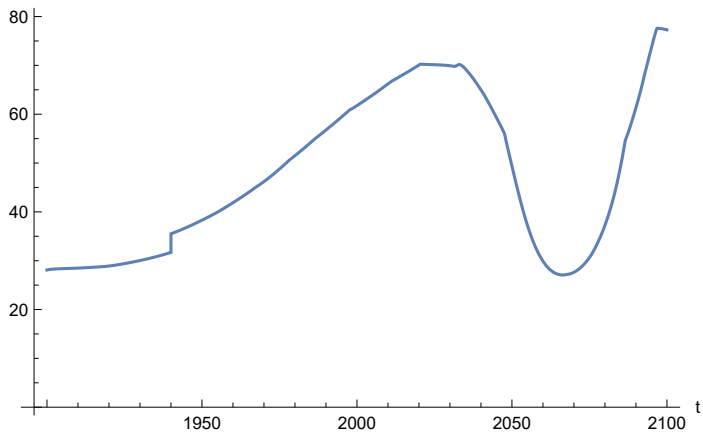
Out[48]=



Plot life expectancy, years.

In[49]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

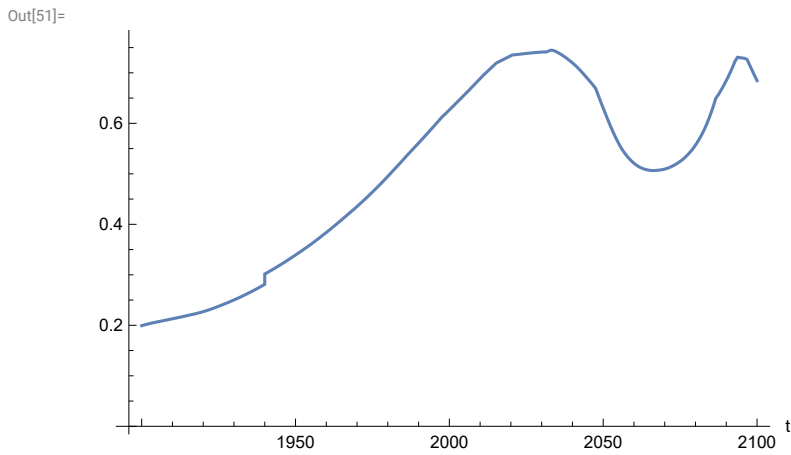
Out[49]=



In[50]:=

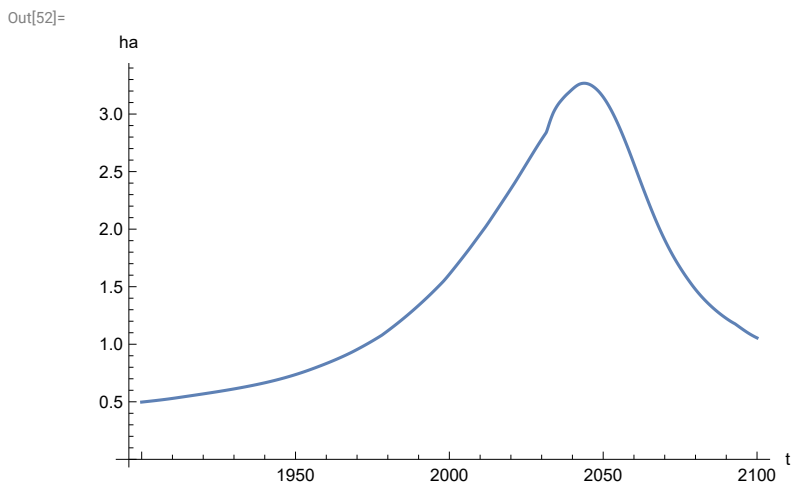
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

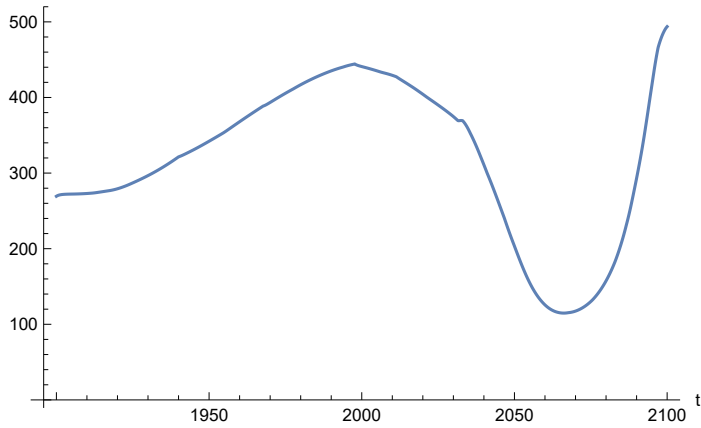
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

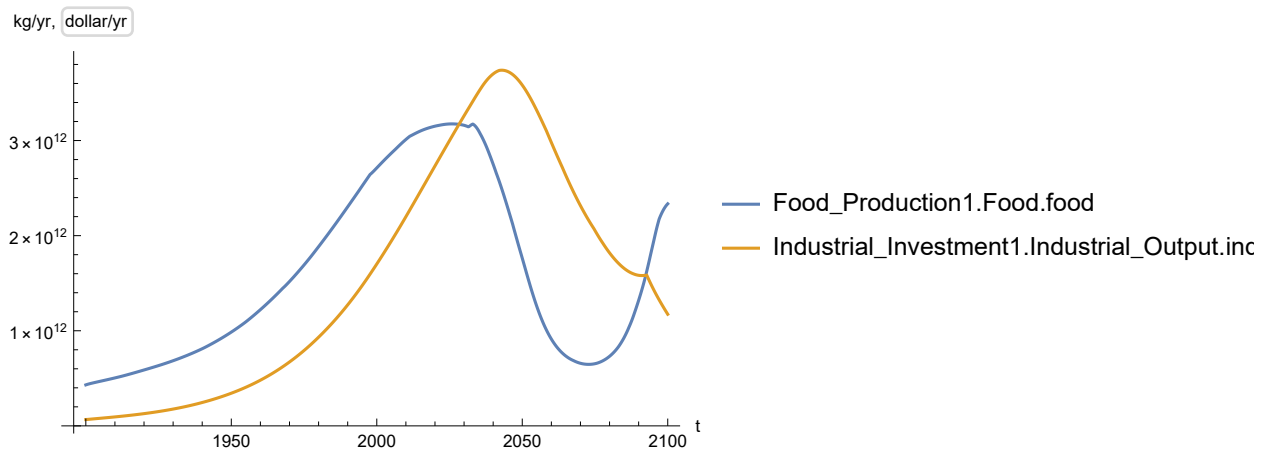
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

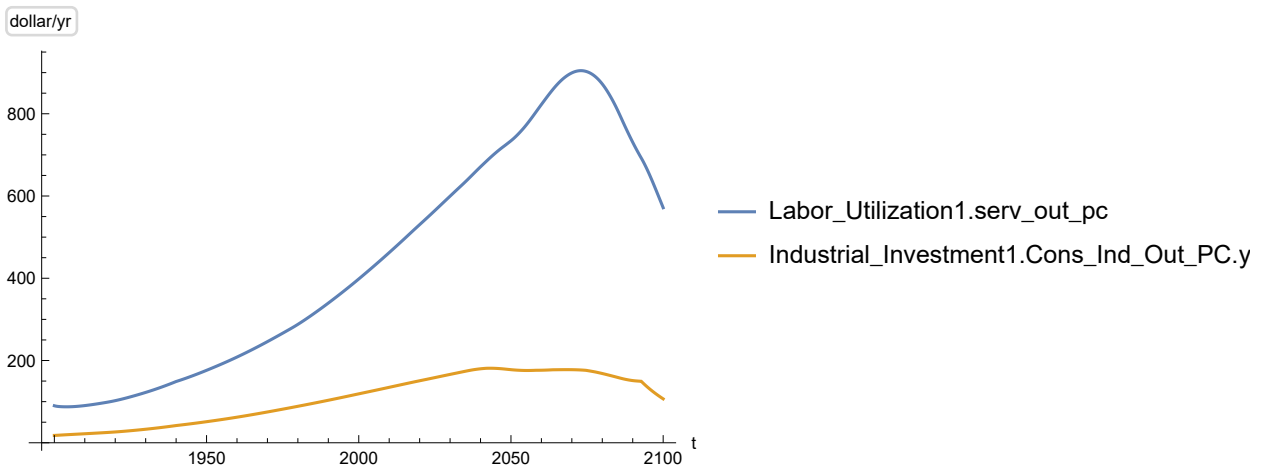
Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[55]=



Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

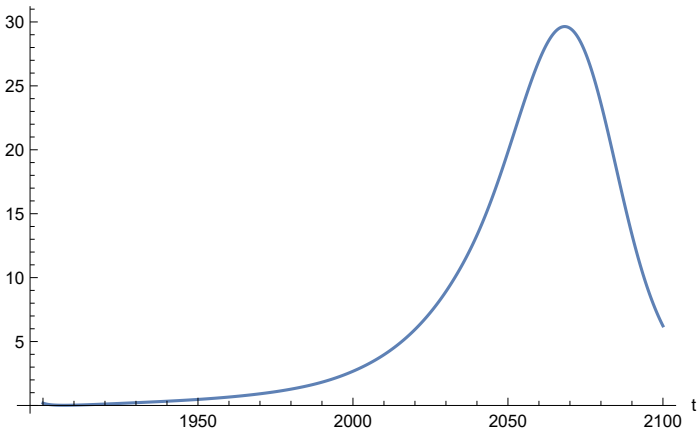
Maximum is 904.787

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[57]=



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

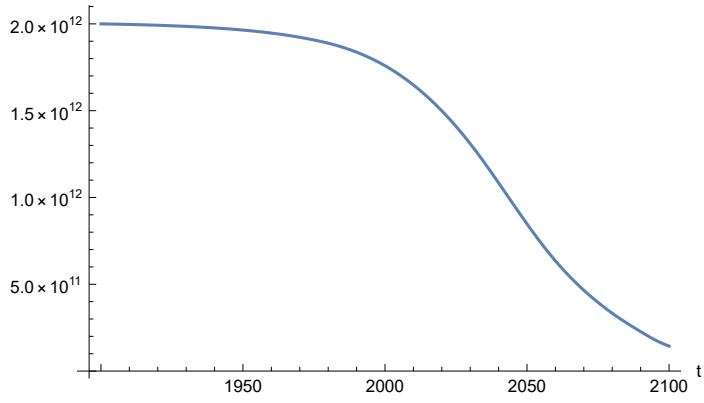
Maximum is 29.6398

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

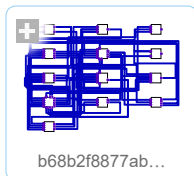


APPENDIX 36. LE/1.05, t_policy_year = 1970. Baseline Scenario 3, Experiment 36.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

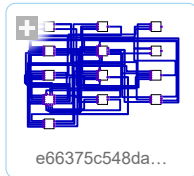
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

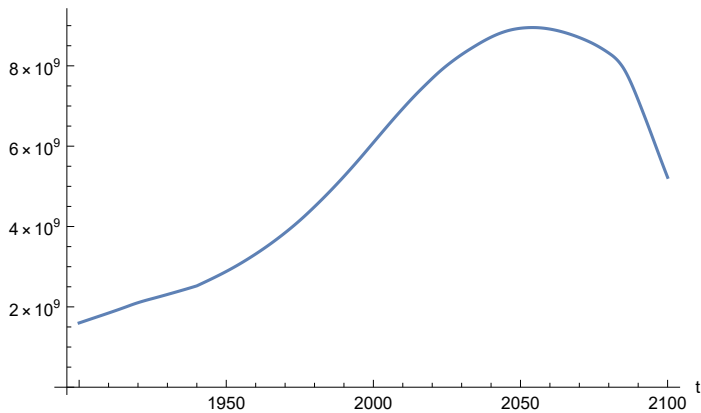
```
Out[69]=
```

```
SystemModelSimulationData [  Model: We66375c548da4a82a7722f4f37f9c8bf  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



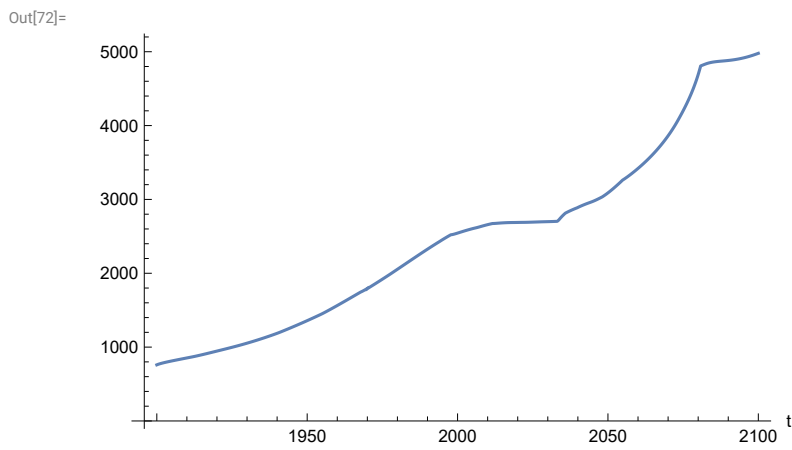
Find max and min of population values.

```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.95283 \times 10^9$ 
```

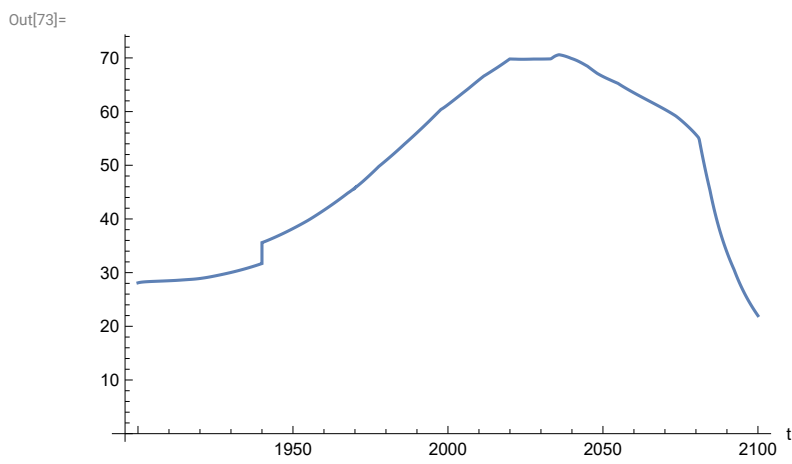
```
Minimum is  $1.6 \times 10^9$ 
```

```
In[72]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```



Plot life expectancy, years.

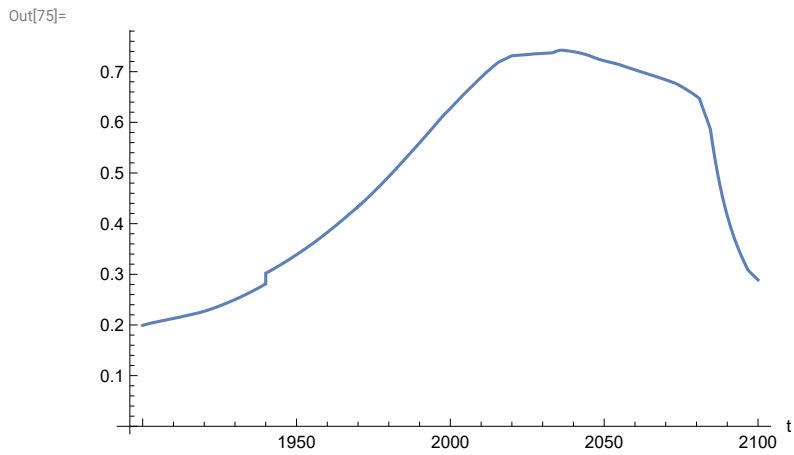
```
In[73]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[74]:=
```

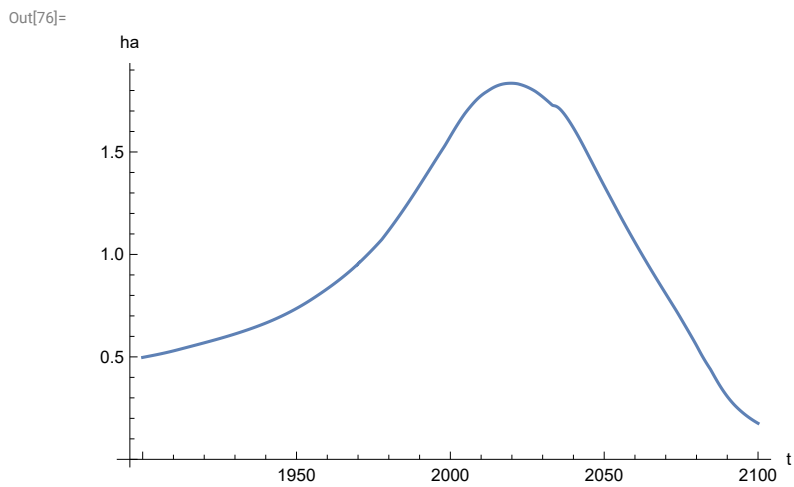
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



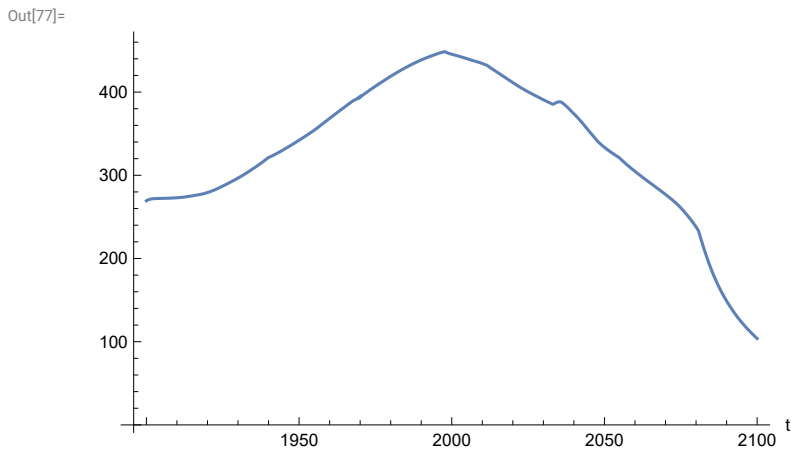
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



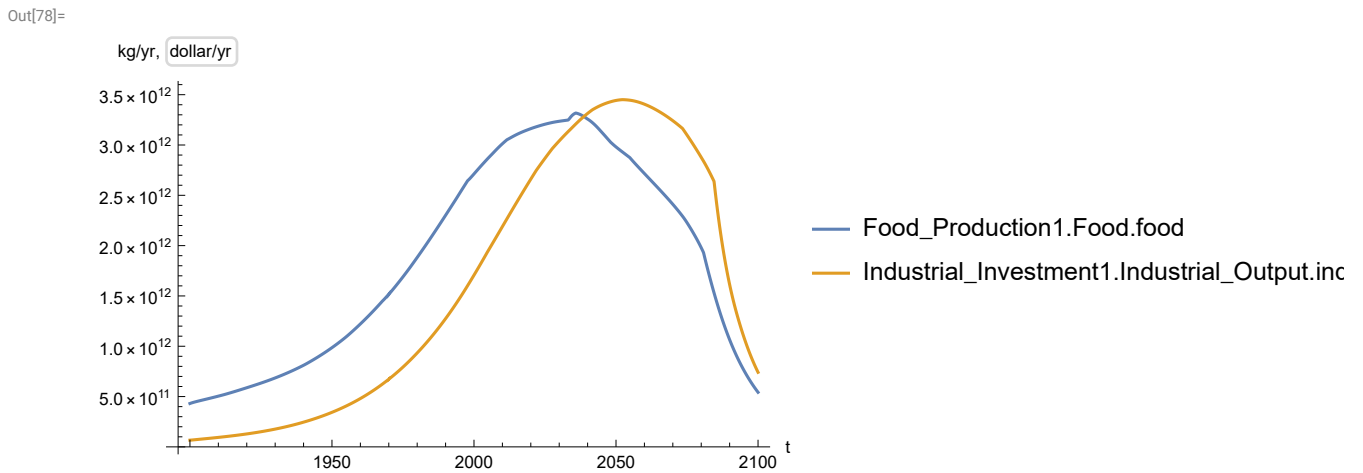
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

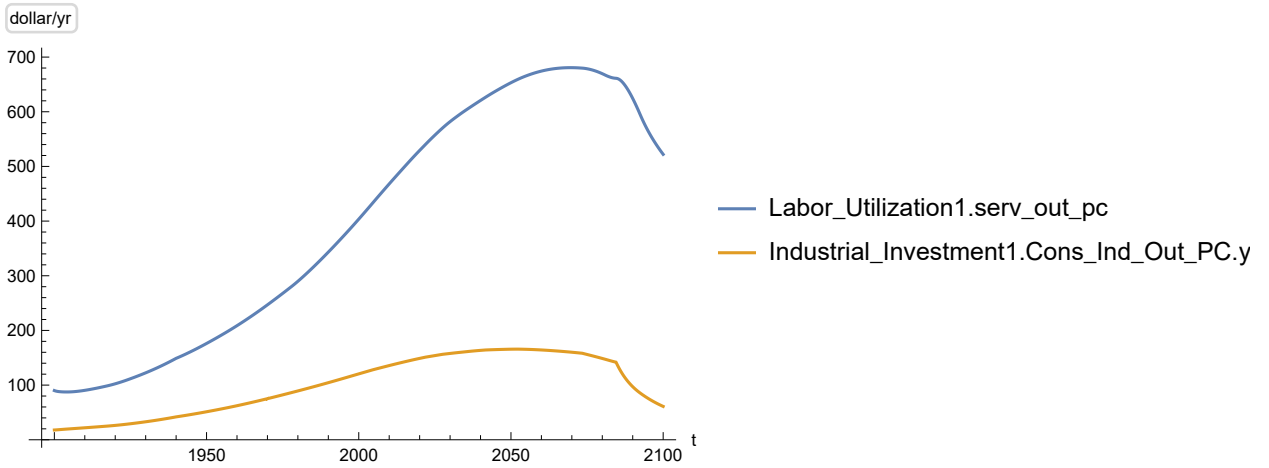
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

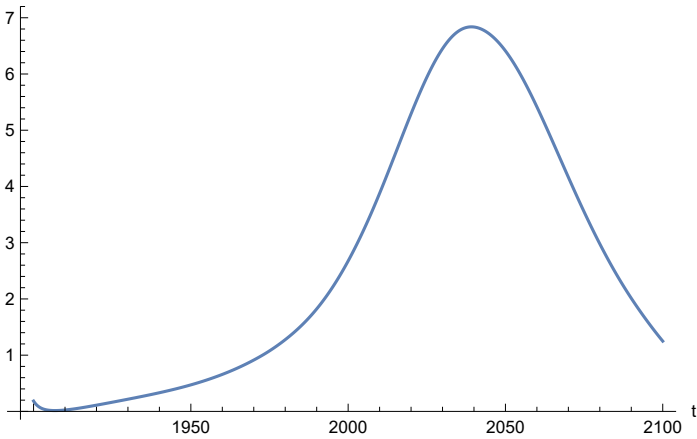
```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 680.67
 Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

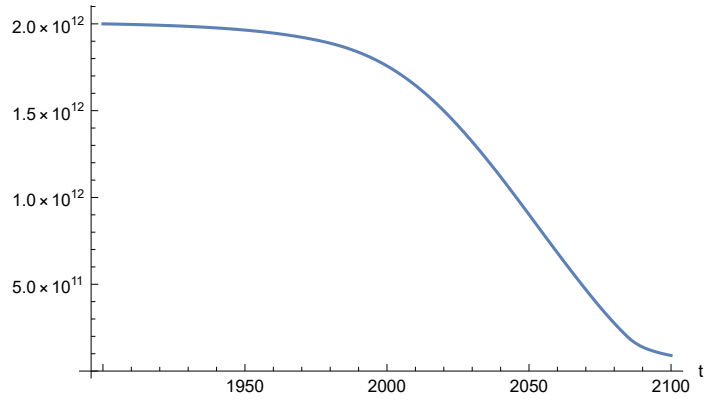
```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 6.83833
 Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

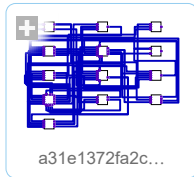
Out[83]=



APPENDIX 37. Baseline Scenario 1, Experiment 37. $LE = LE/1.05$, $t_policy_year = 2025$.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

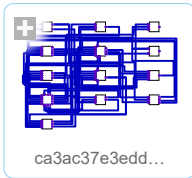
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 2025.



```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

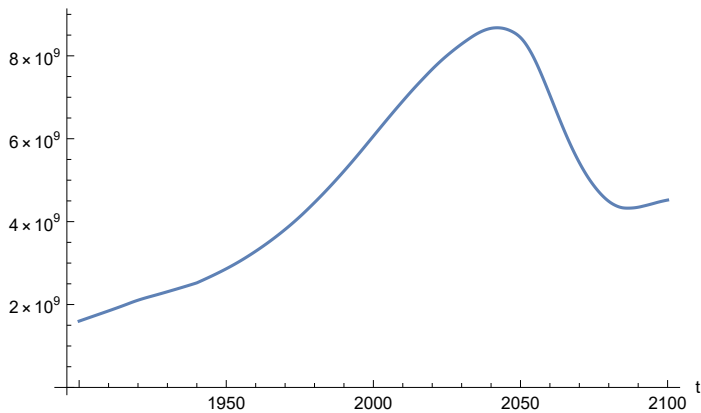
```
Out[93]=
```

```
SystemModelSimulationData [   Model: Wca3ac37e3edd49ab81ac00181d5ae6ee  
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[94]=
```



Find max and min of population values.

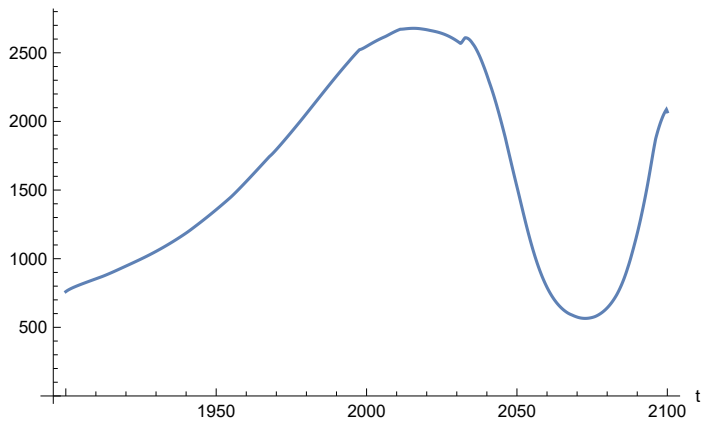
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.67683 × 109
```

```
Minimum is 1.6 × 109
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

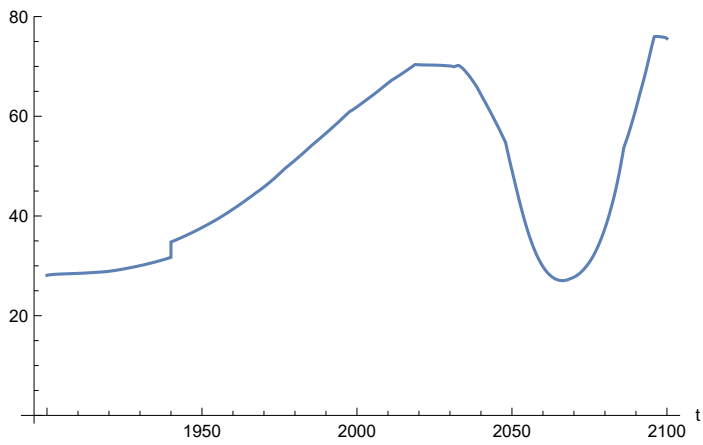
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

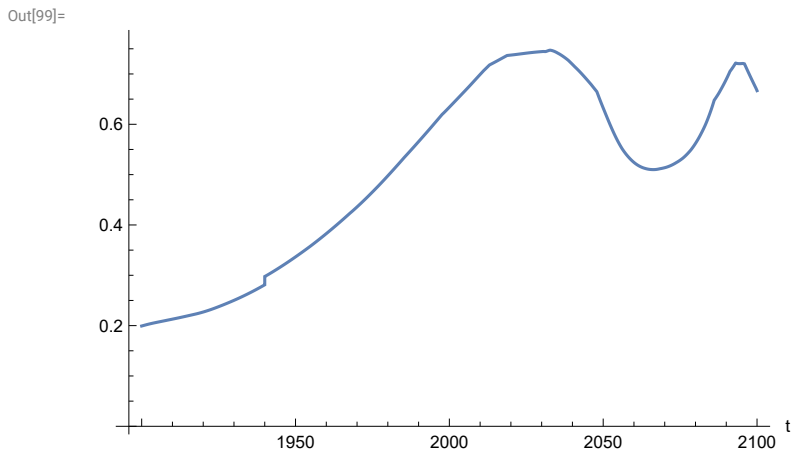
Out[97]=



In[98]=

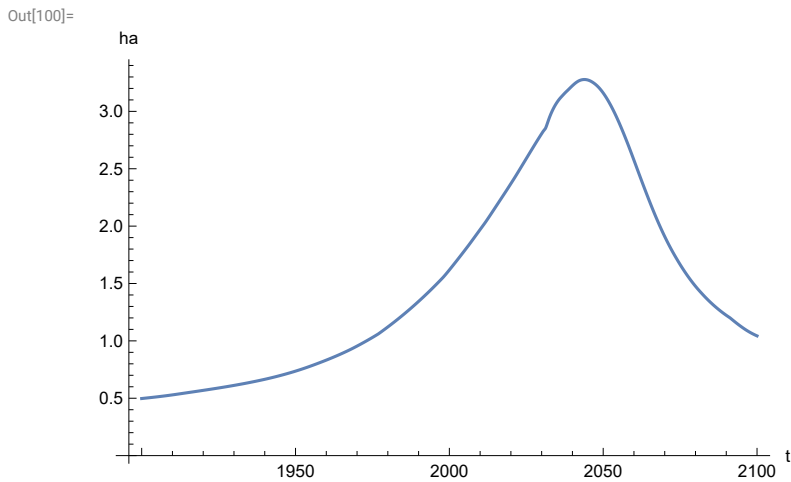
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



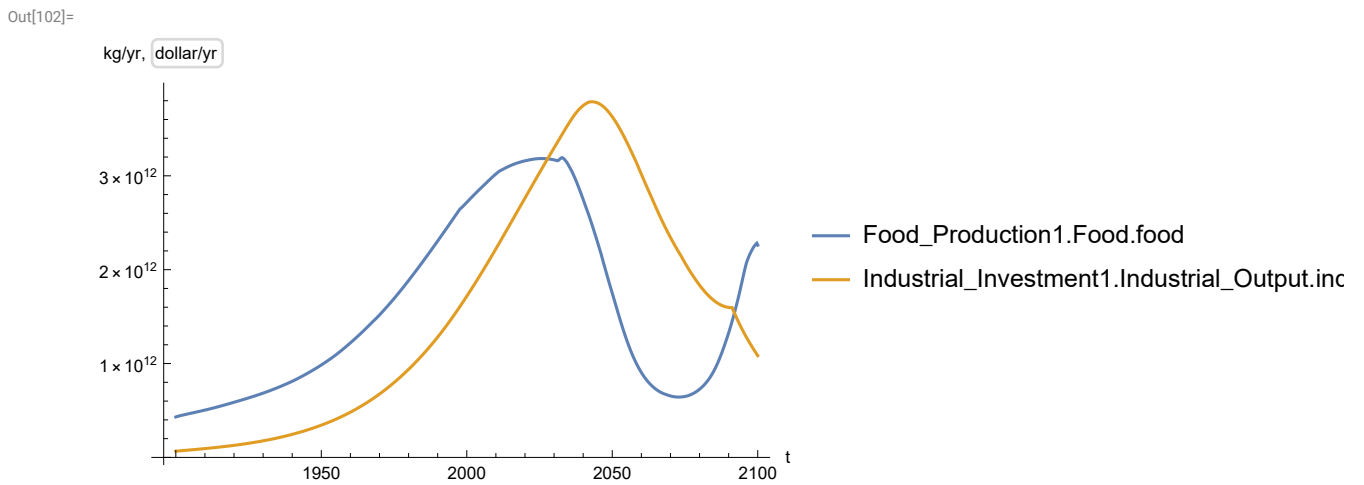
Plot food production per capita (kg/year).

```
In[101]:=
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[102]:=
SystemModelPlot[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]
```

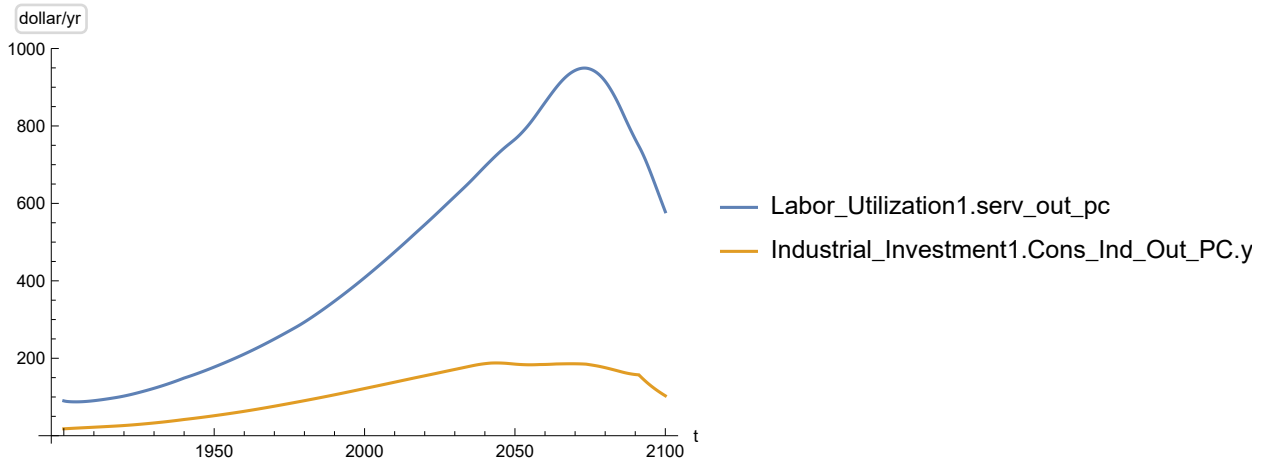


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

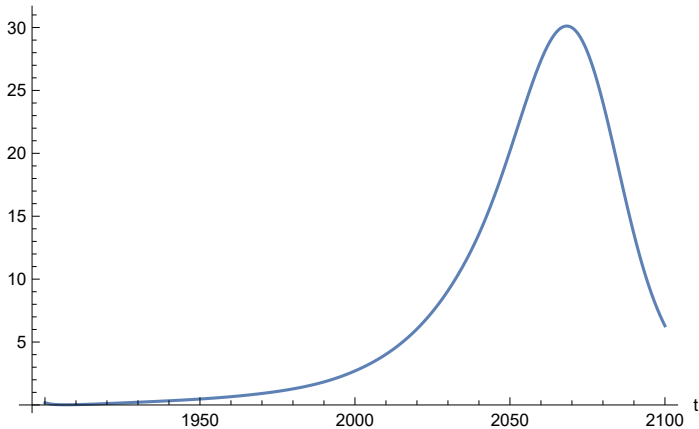
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 949.517
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 30.1177

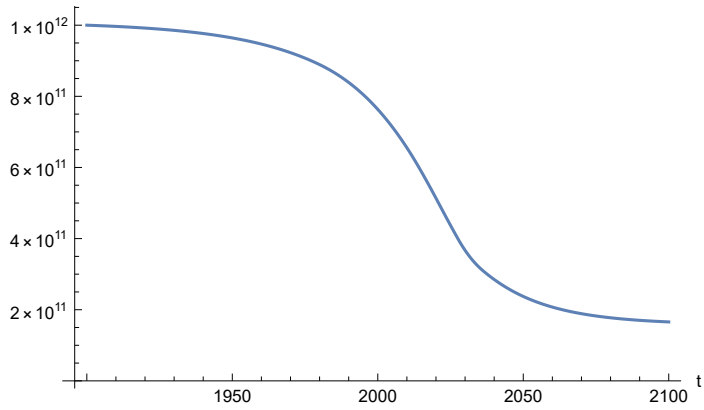
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 38. BENCHMARK SCENARIO 13, Experiment 38. $LE = LE/1.1$, $t_{policy_year} = 1970$.
Last modified: 28 July 2022/1415 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

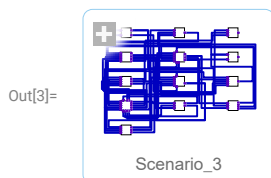
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

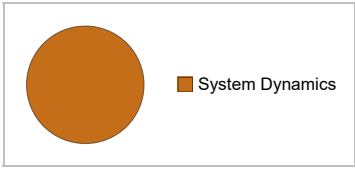
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 3.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_3"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_3
	Description	More accessible non-recoverable natural resources and pollution control
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

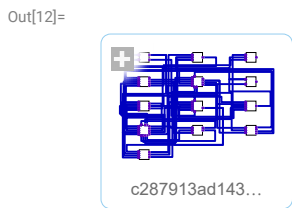
```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

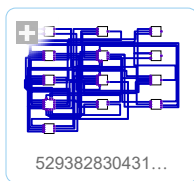
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

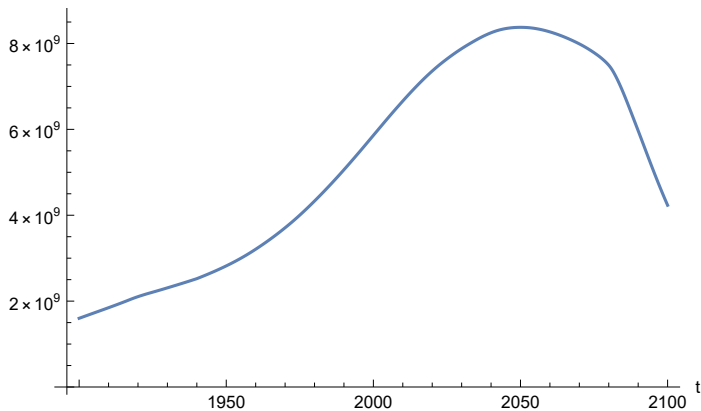
```
Out[21]=
```

```
SystemModelSimulationData [
  Model: W5293828304314f29ace9167675676d81
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$ 
]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

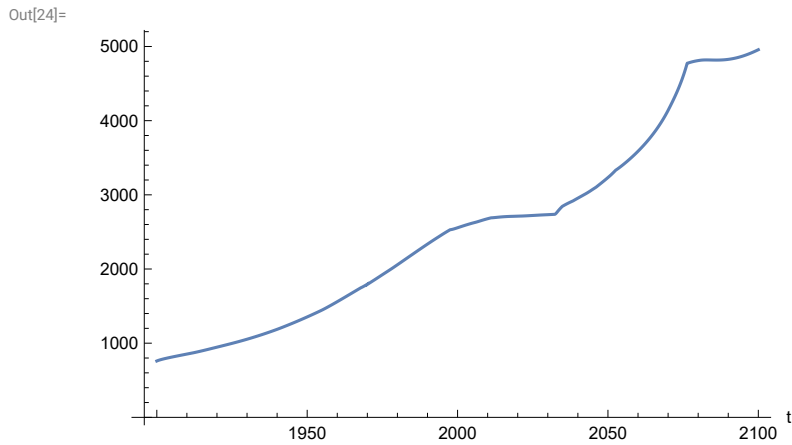
```
Out[22]=
```



Find max and min of population values.

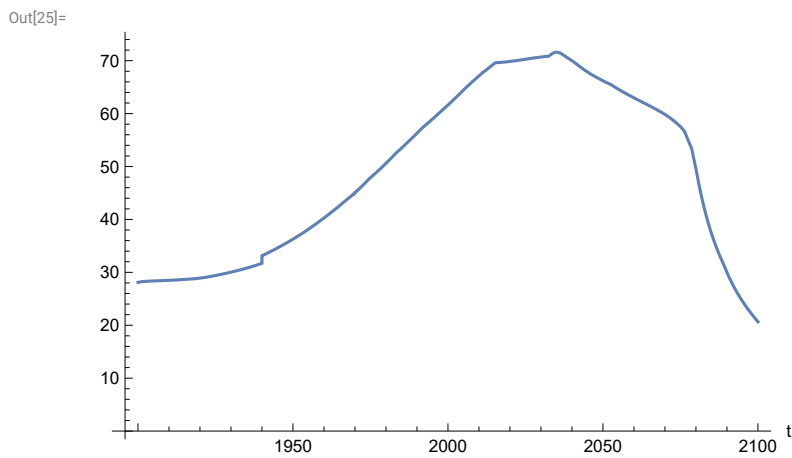
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.37619 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

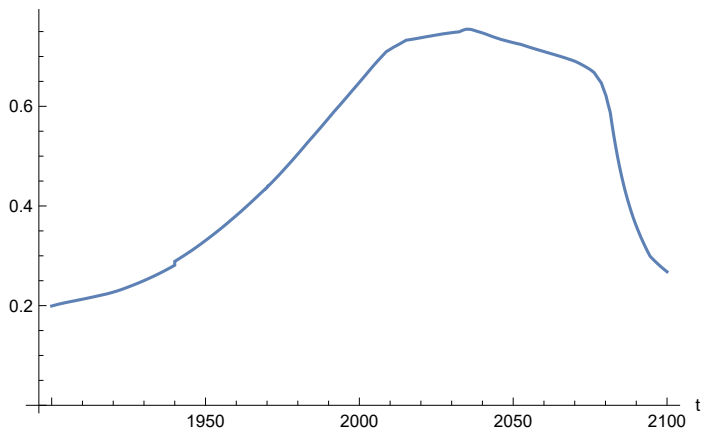


```
In[26]:=
```

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

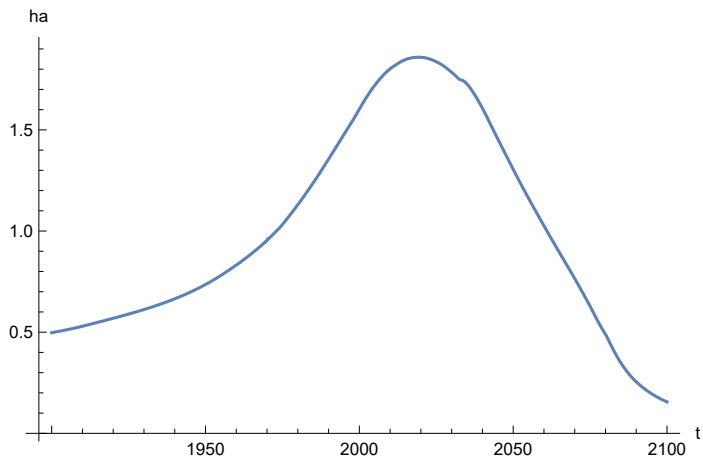
Out[27]=



Plot per capita ecological footprint, hectares.

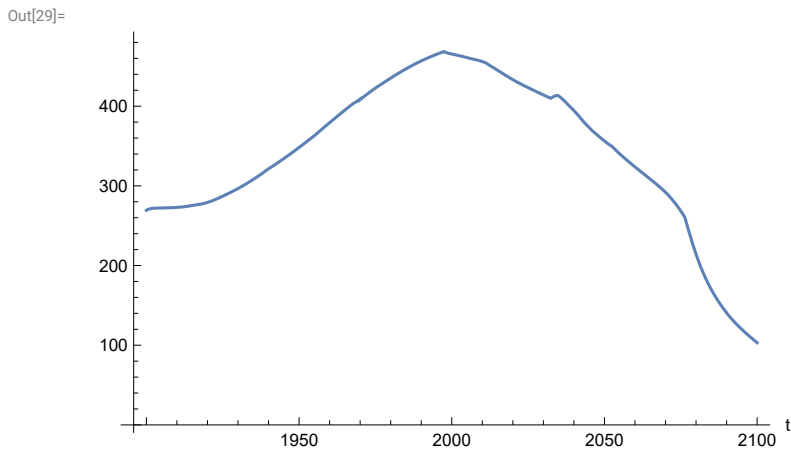
```
In[28]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

Out[28]=



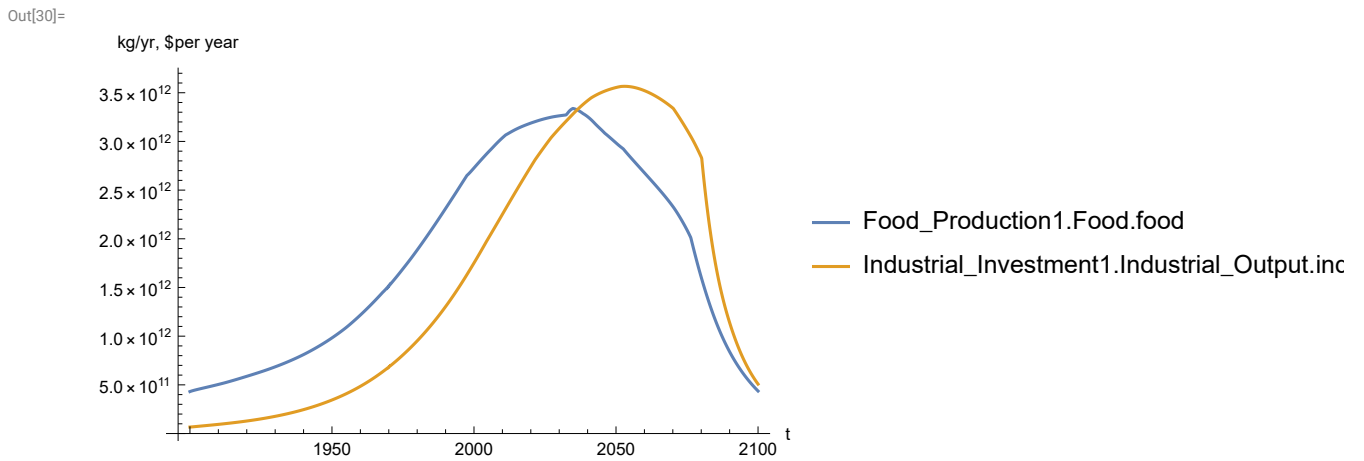
Plot food production per capita (kg/year).

```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



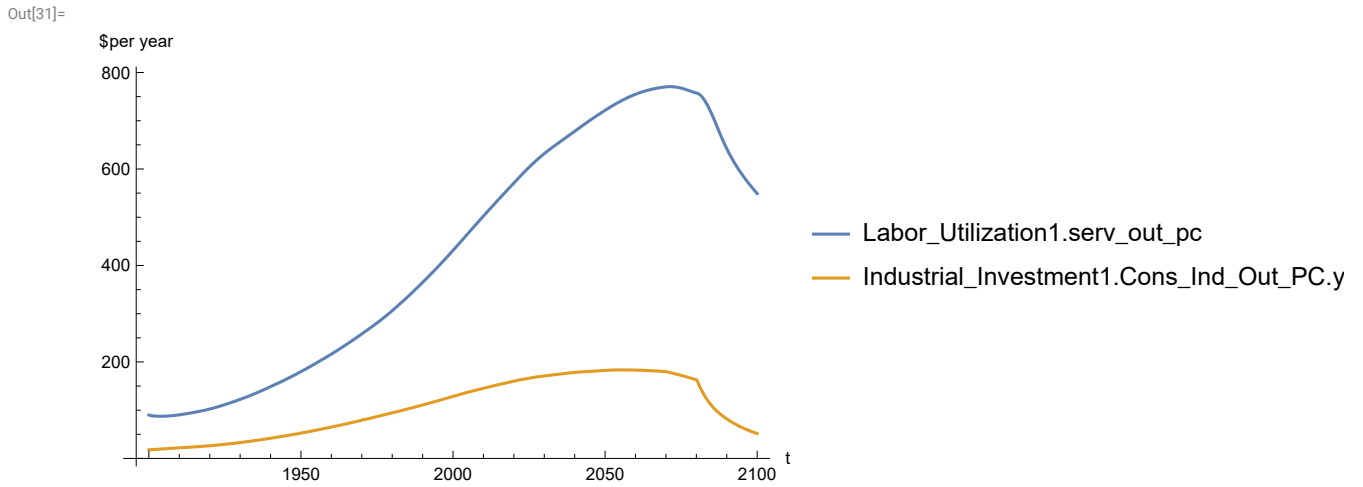
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

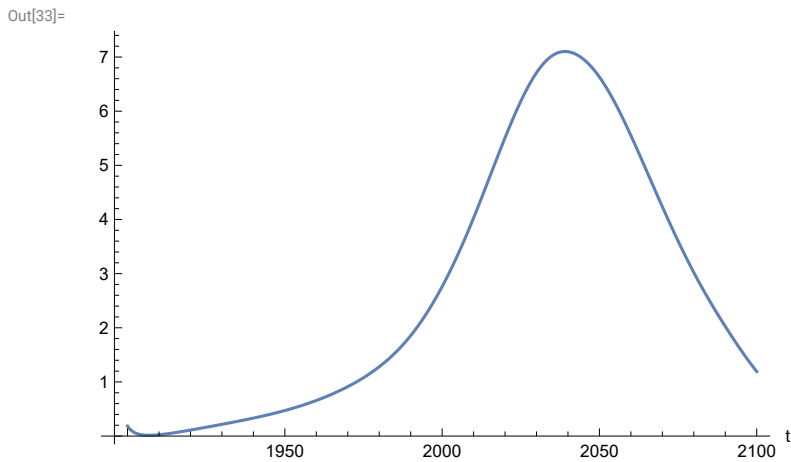


Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 770.704
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



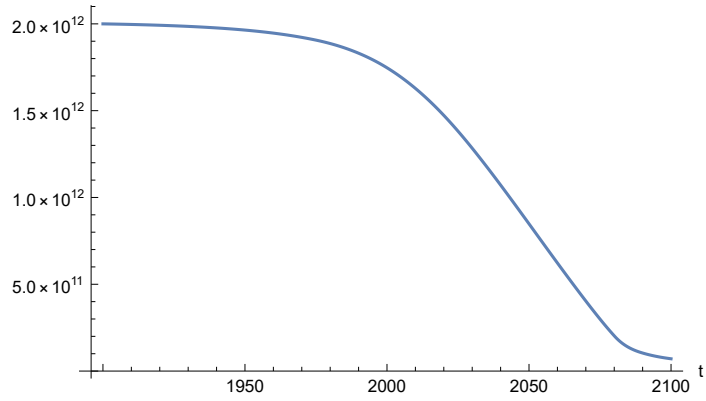
Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 7.10192
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

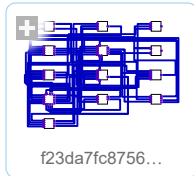


APPENDIX 39. LE/1.1, t_policy_year = 2025. Baseline Scenario 3, Experiment 39.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

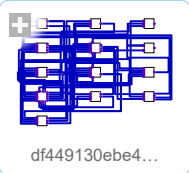
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}>|>]
```

Out[44]=  df449130ebe4...

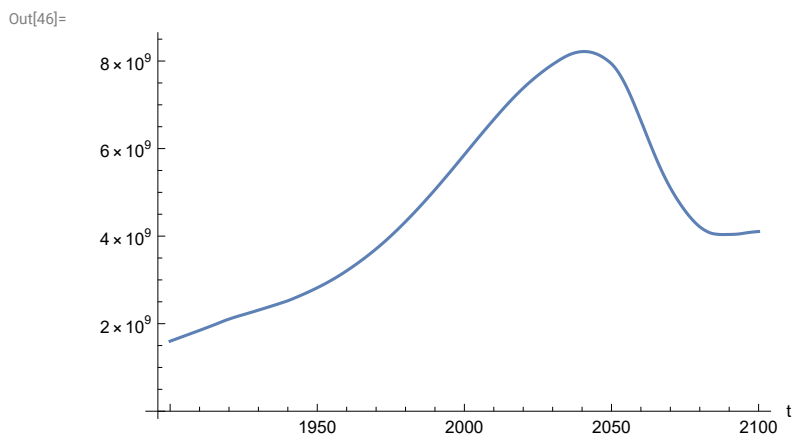
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: Wdf449130ebe44842a531cc8acf15102b
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

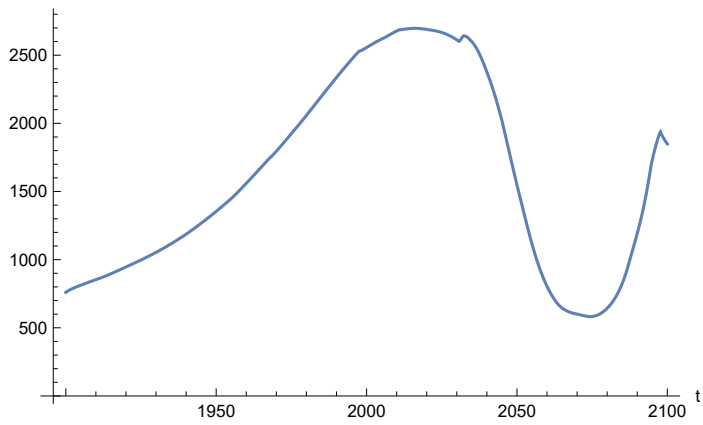
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.21714×10^9

Minimum is 1.6×10^9

In[48]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

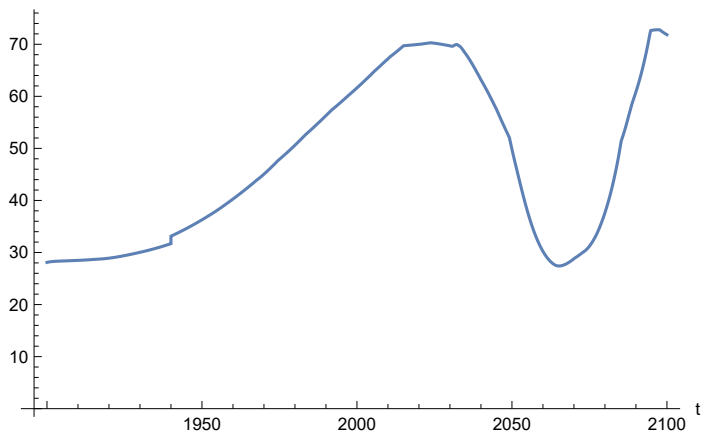
Out[48]=



Plot life expectancy, years.

In[49]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

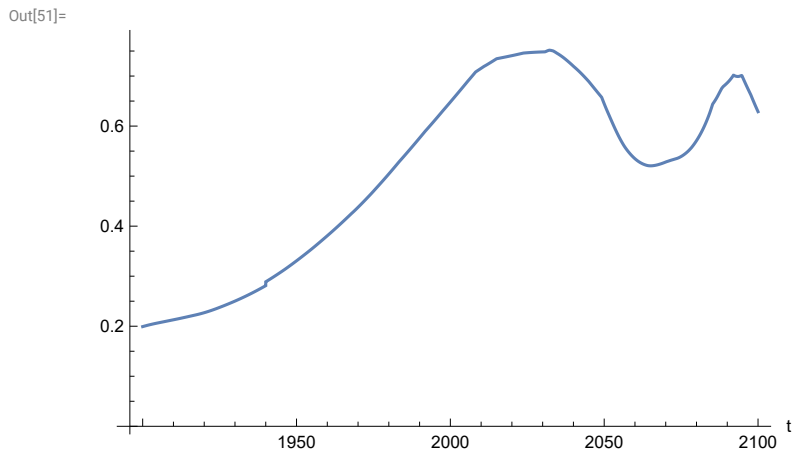
Out[49]=



In[50]:=

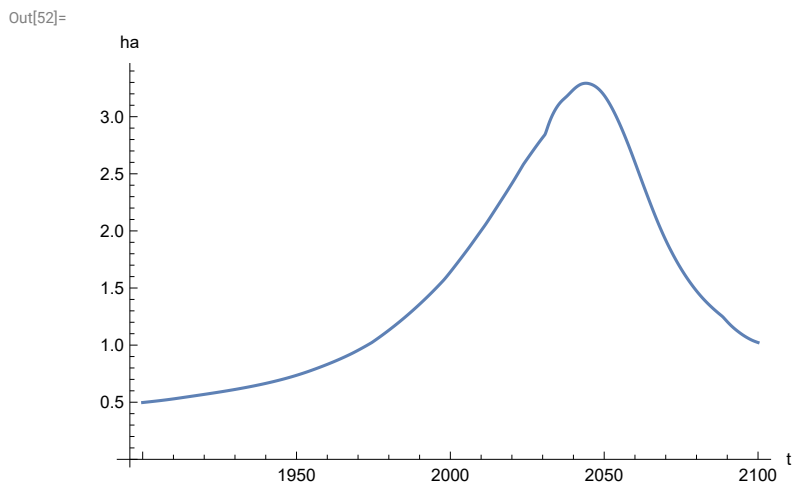
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

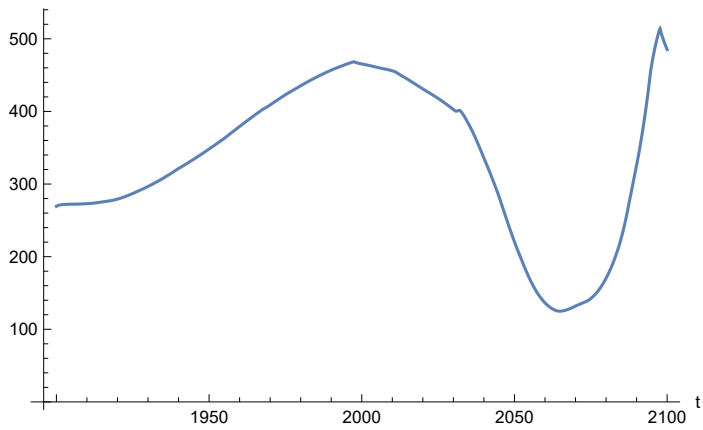
```
In[52]:= SystemModelPlot[basesim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

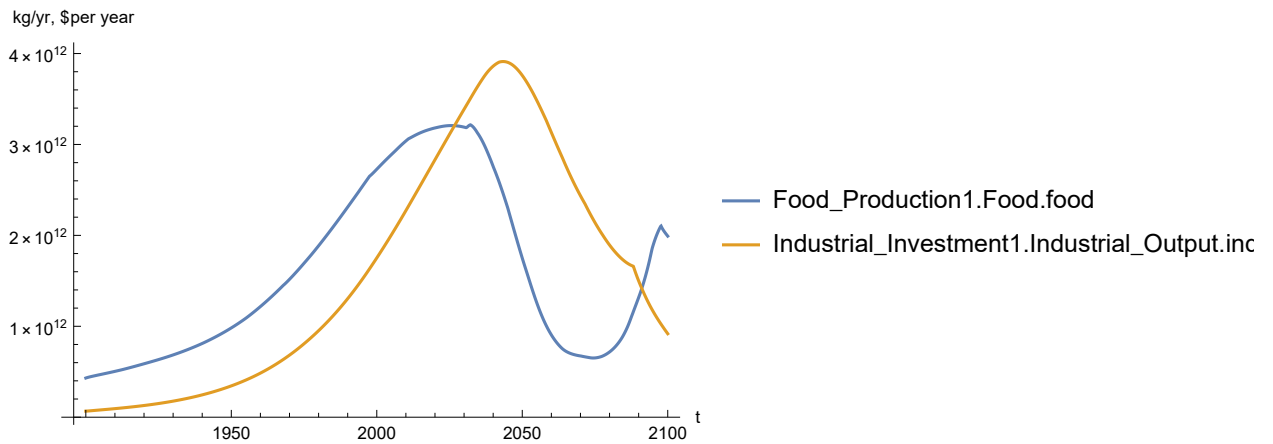
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

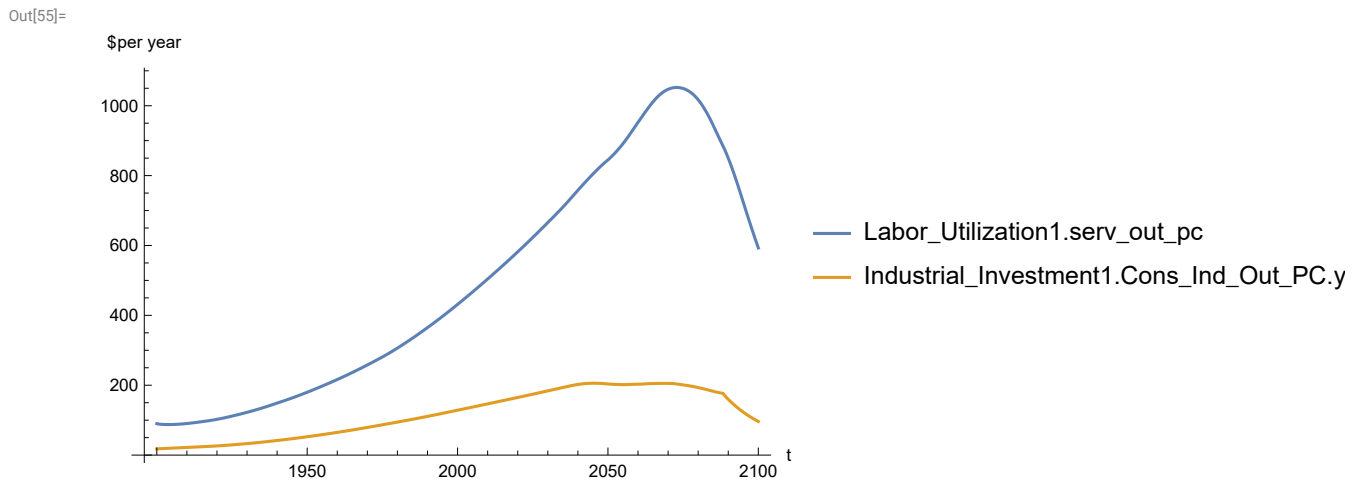
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

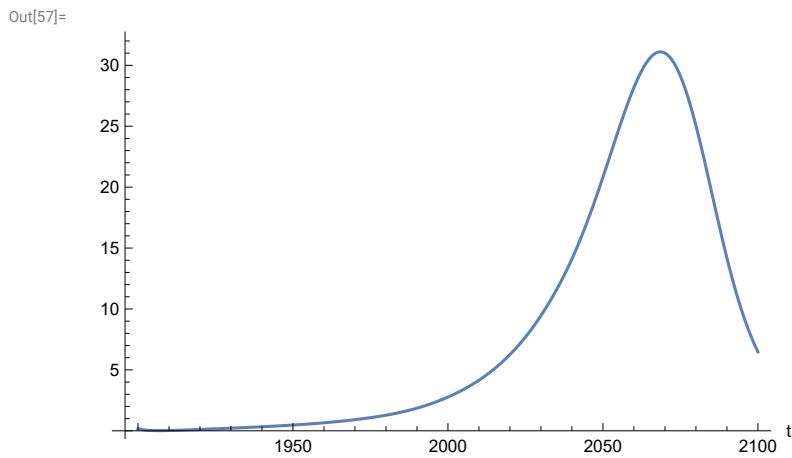
```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1052.28

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

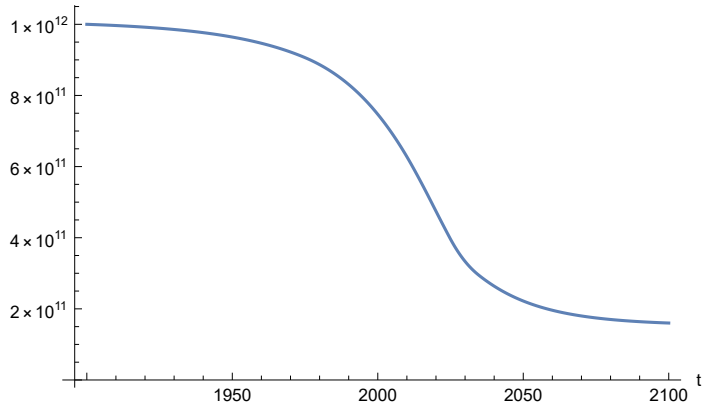
Maximum is 31.1036

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=



APPENDIX 3A1. BENCHMARK SCENARIO 8, Experiment 3A1. $LE = LE/1.001$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1210 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

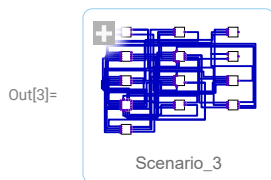
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

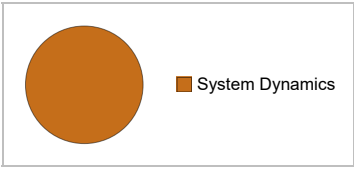
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 3.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_3"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_3
	D	More accessible non-recoverable natural resources and pollution control
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

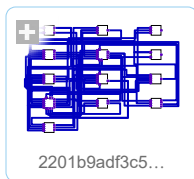
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```


```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

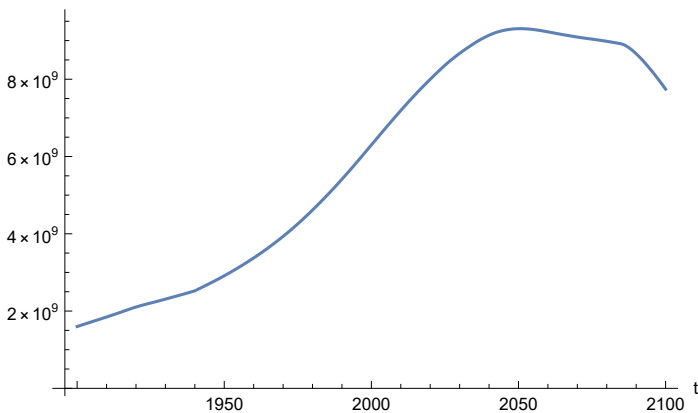
```
Out[20]=
```

```
SystemModelSimulationData [  Model: W2201b9adf3c54a5c95d07d0823dab294  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

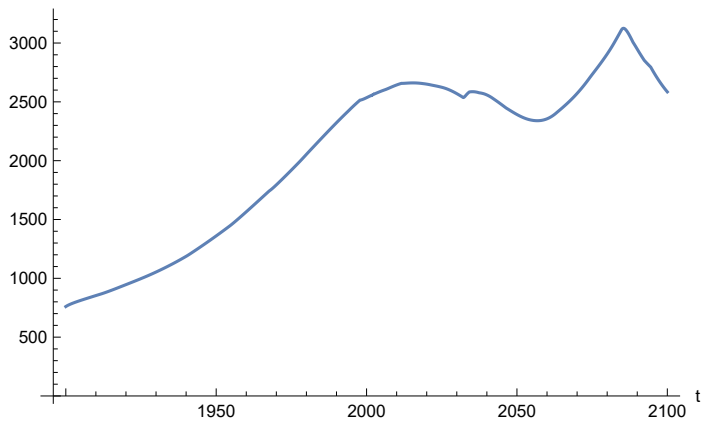
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.30865 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[23]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

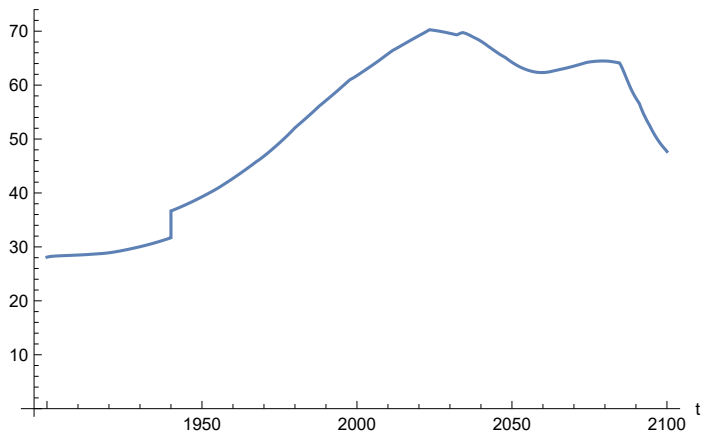
Out[23]=



Plot life expectancy, years.

```
In[24]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

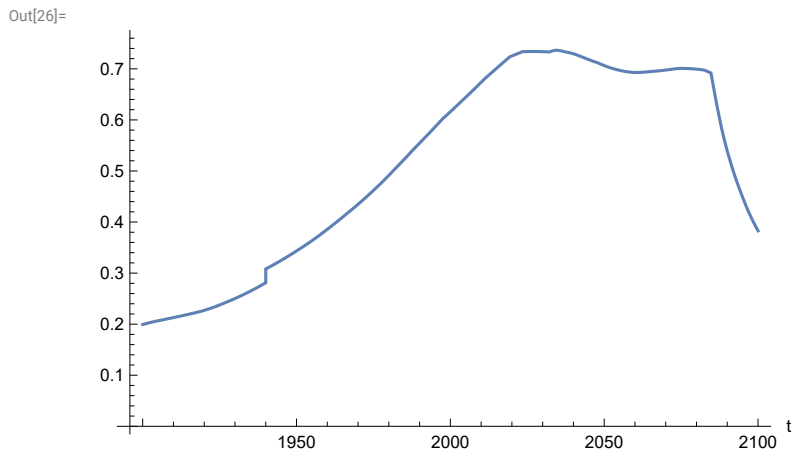
Out[24]=



In[25]=

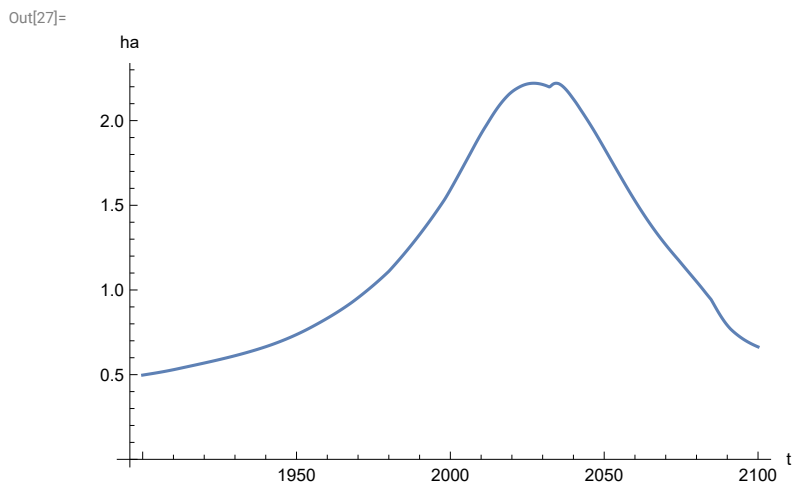
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

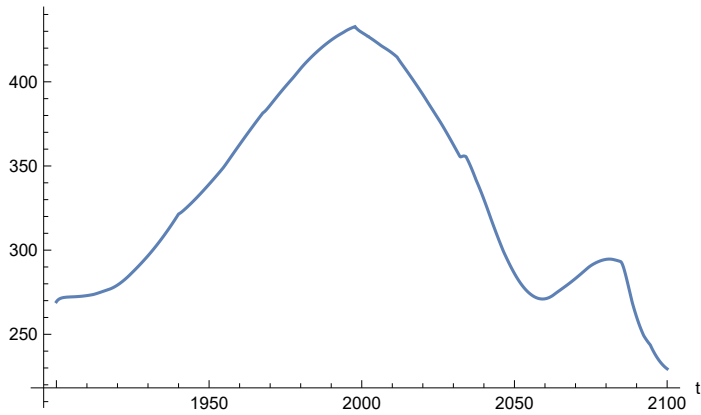
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

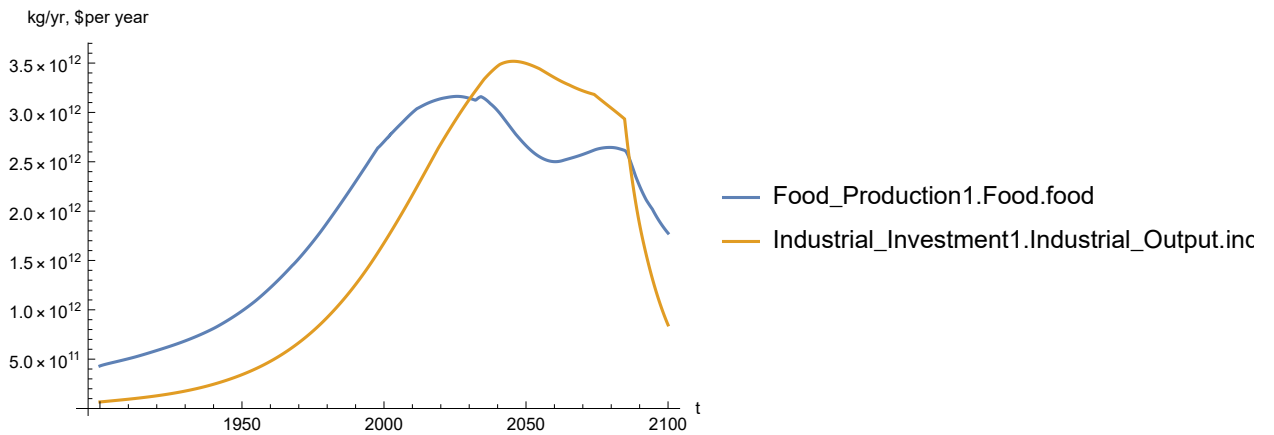
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

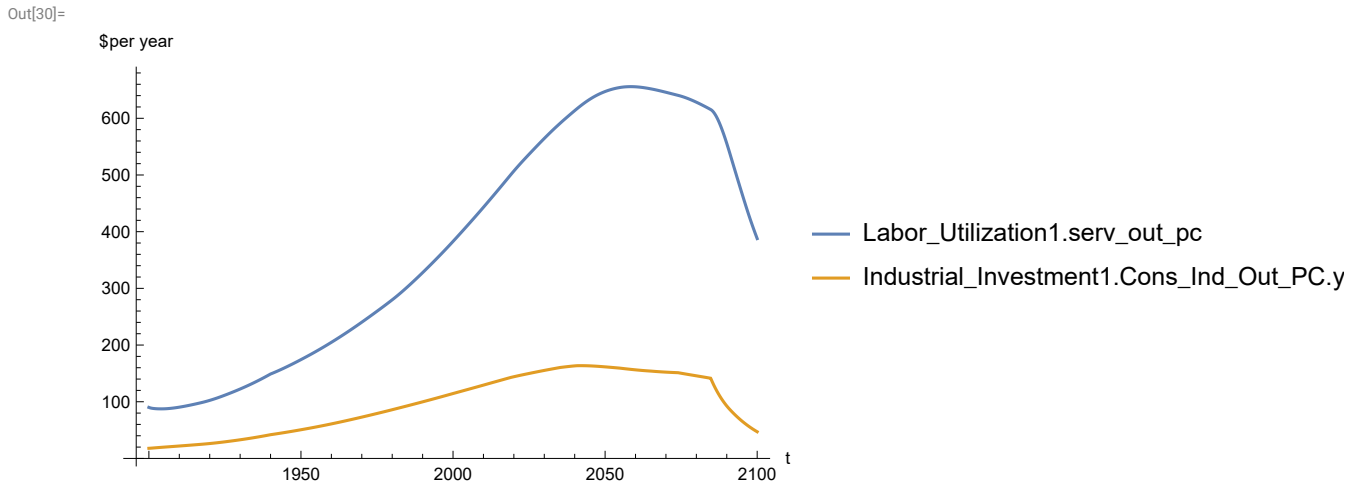
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

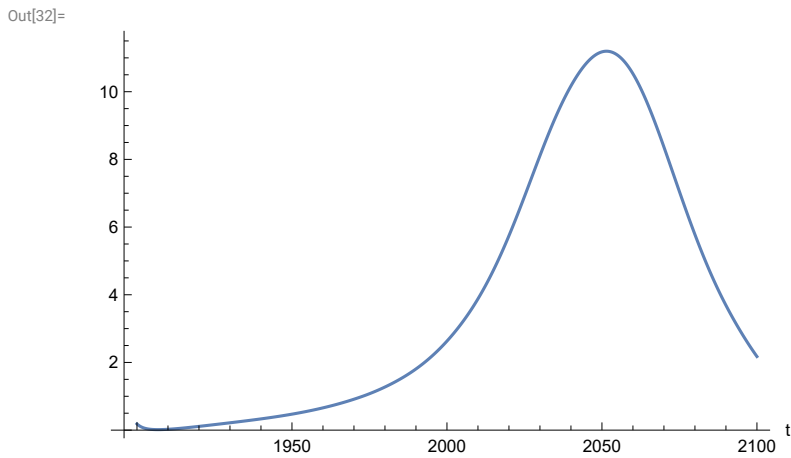


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 655.832
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



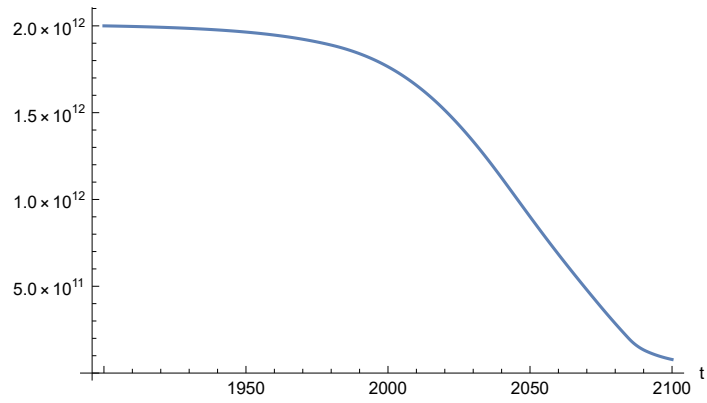
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.1964
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

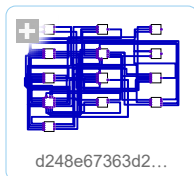


APPENDIX 3A2. LE/1.01, t_policy_year =2002. Baseline Scenario 8, Experiment 3A2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=


```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

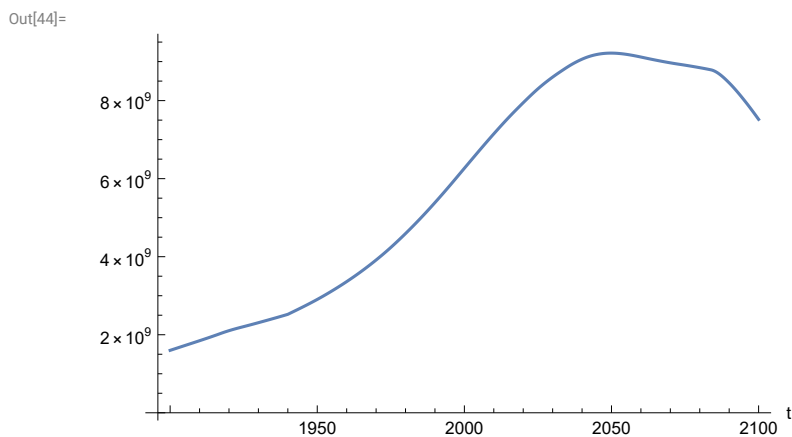
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: Wd248e67363d246febc53b1f9bdb62749
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

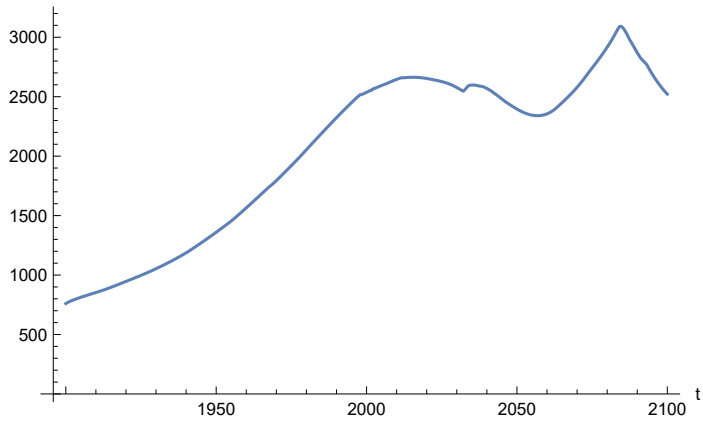
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.21719 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[46]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

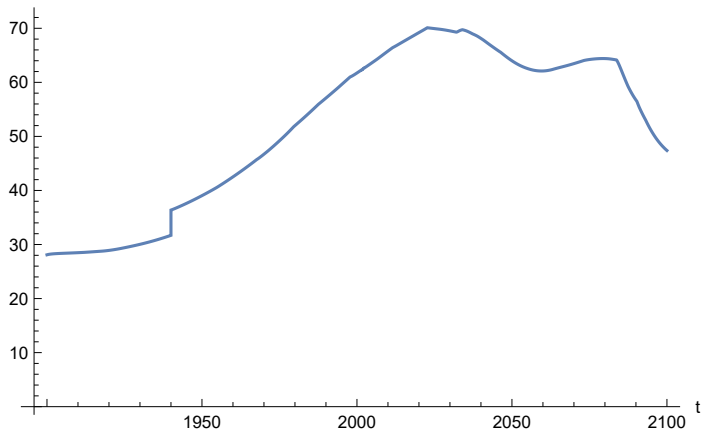
Out[46]=



Plot life expectancy, years.

In[47]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

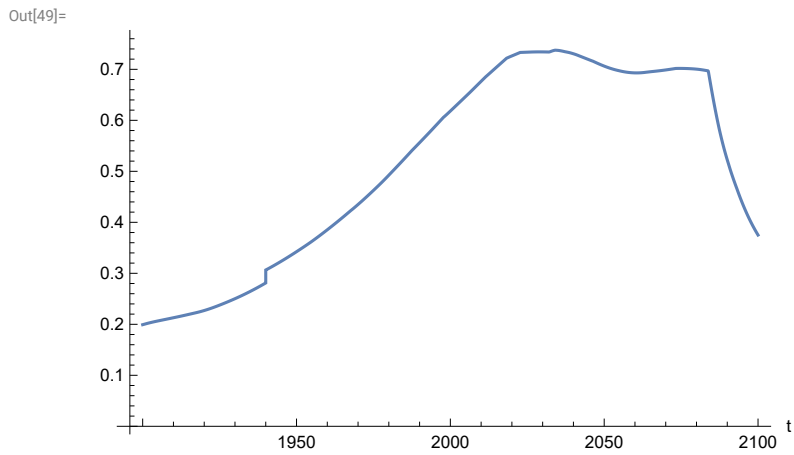
Out[47]=



In[48]:=

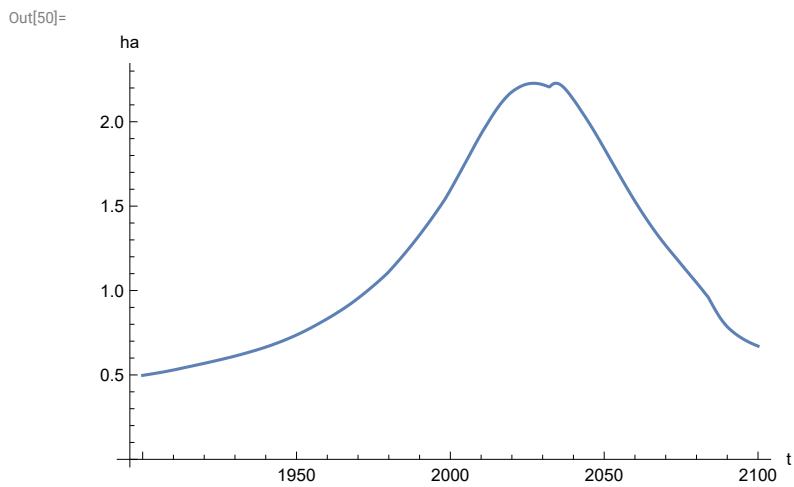
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

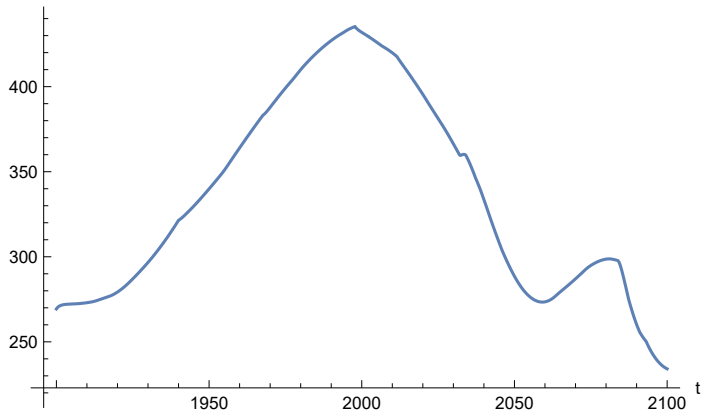
```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]**

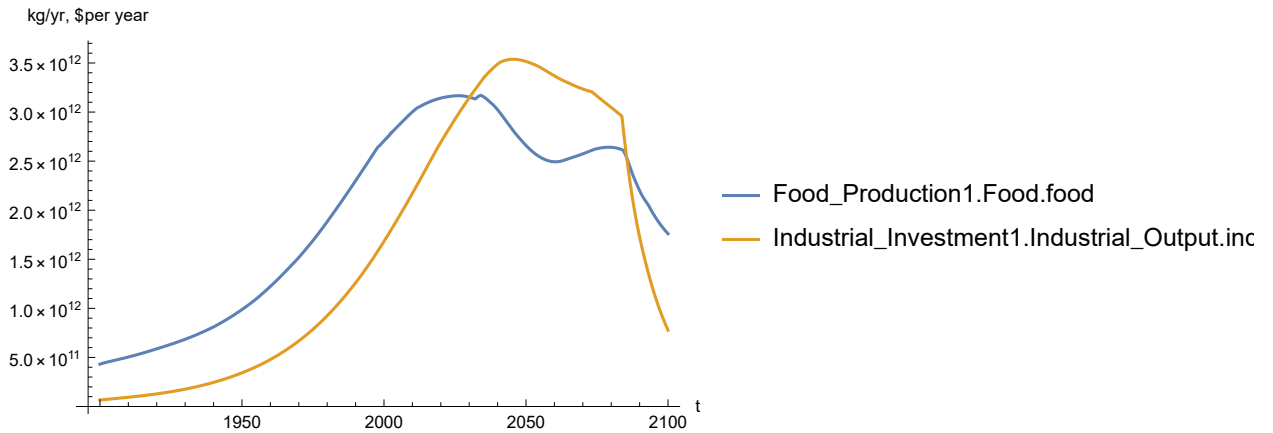
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

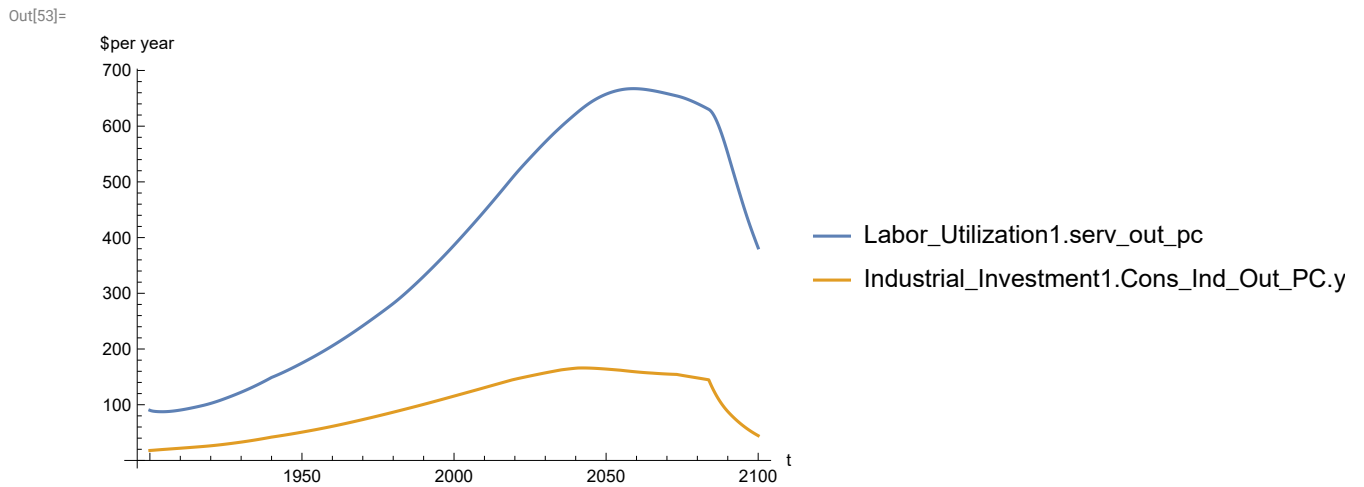
In[52]:= **SystemModelPlot[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

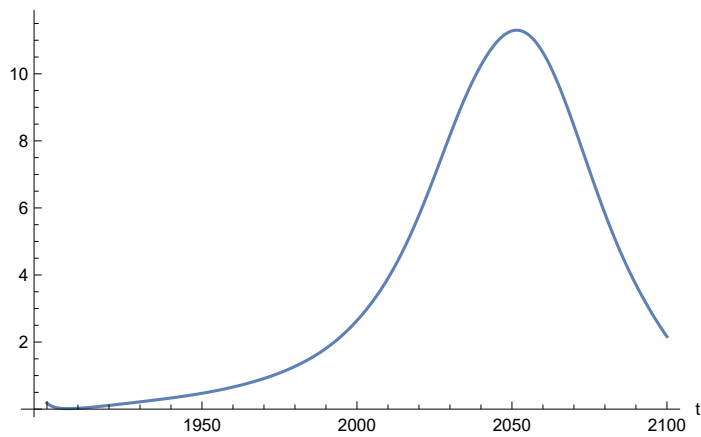


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 667.356
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



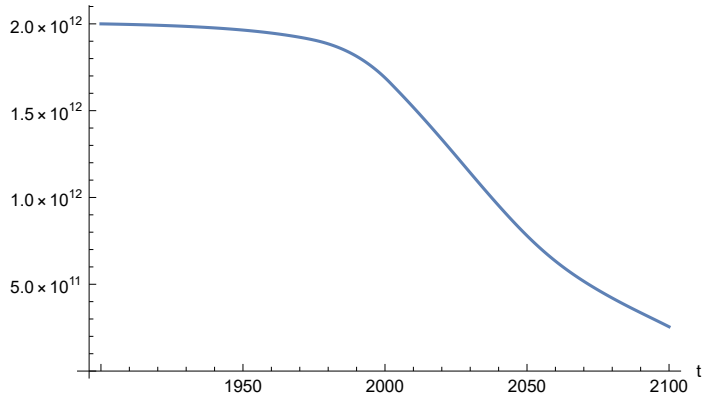
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.2995
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 3B1. BENCHMARK SCENARIO 8, Experiment 3B1. $LE = LE/1.03$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1430 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

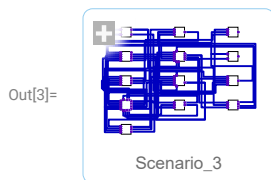
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

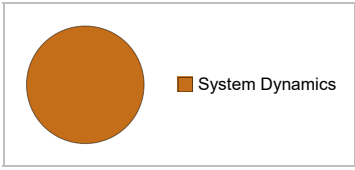
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 3.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_3"]
```



In[4]:= **mysummary = mysim["Summary"]**

	Model	SystemDynamics.WorldDynamics.World3.Scenario_3
	Description	More accessible non-recoverable natural resources and pollution control
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background Color	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

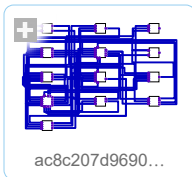
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```


```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

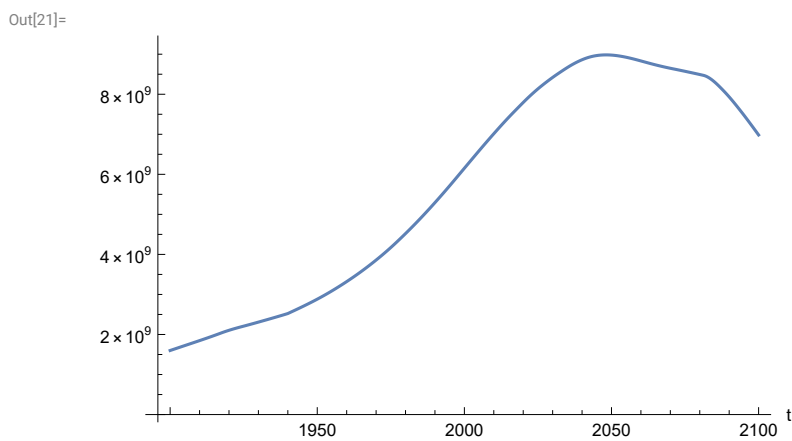
Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

```
Out[20]= SystemModelSimulationData [  Model: Wac8c207d9690408798c564ce5da05b14
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

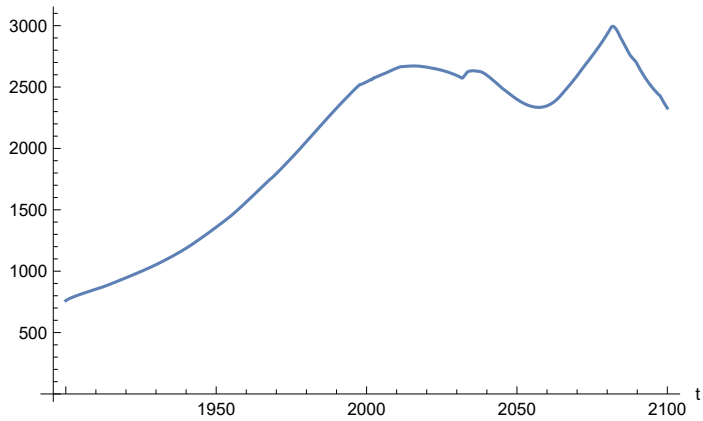
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.9829 × 109
```

```
Minimum is 1.6 × 109
```

In[23]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

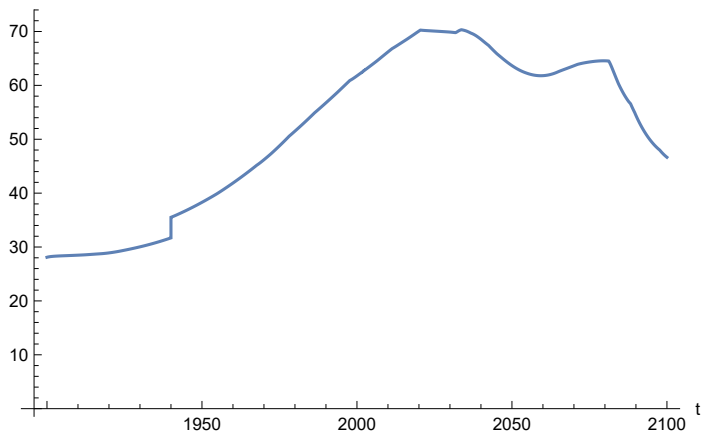
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

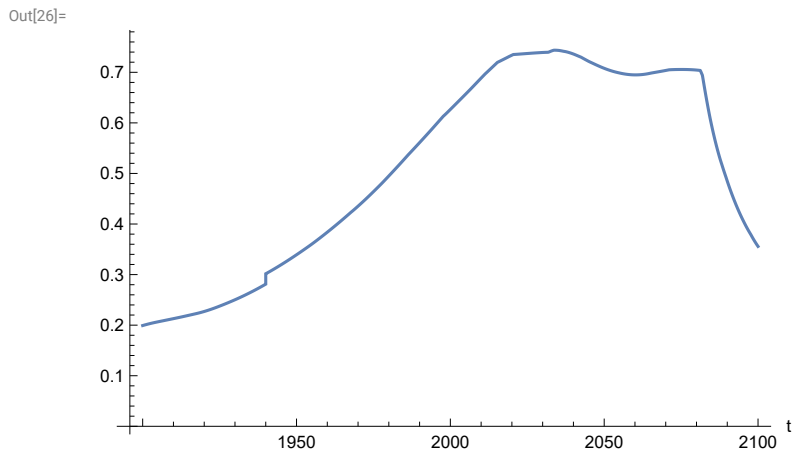
Out[24]=



In[25]:=

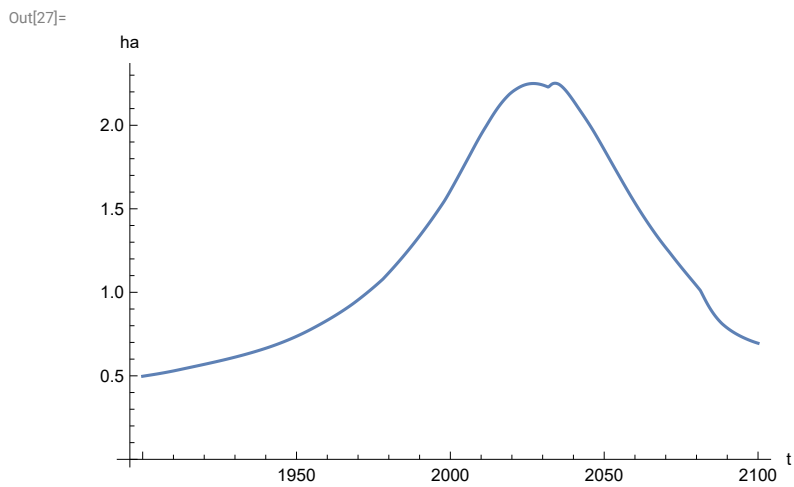
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



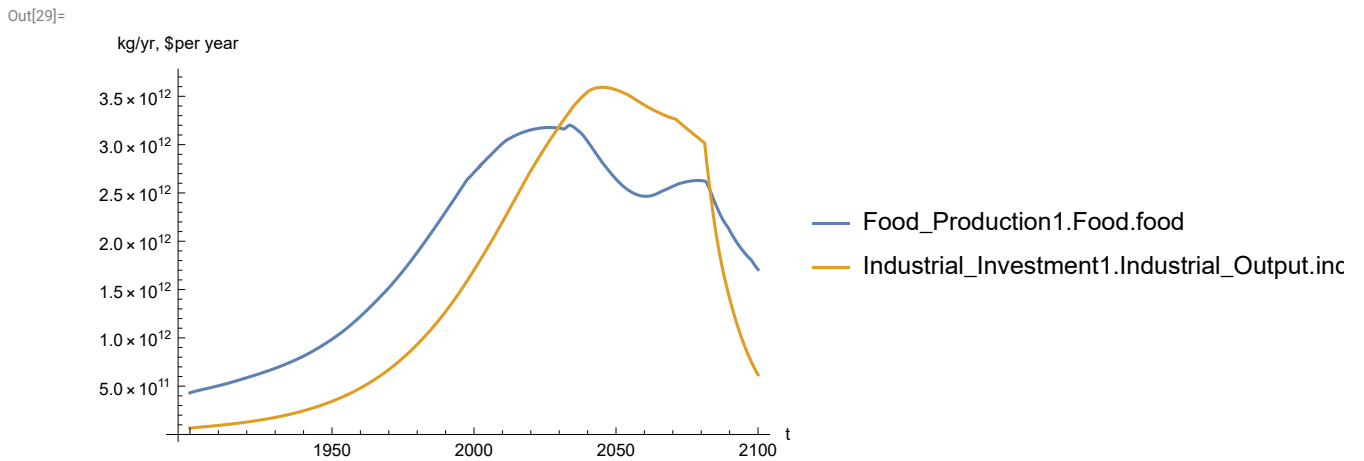
Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]



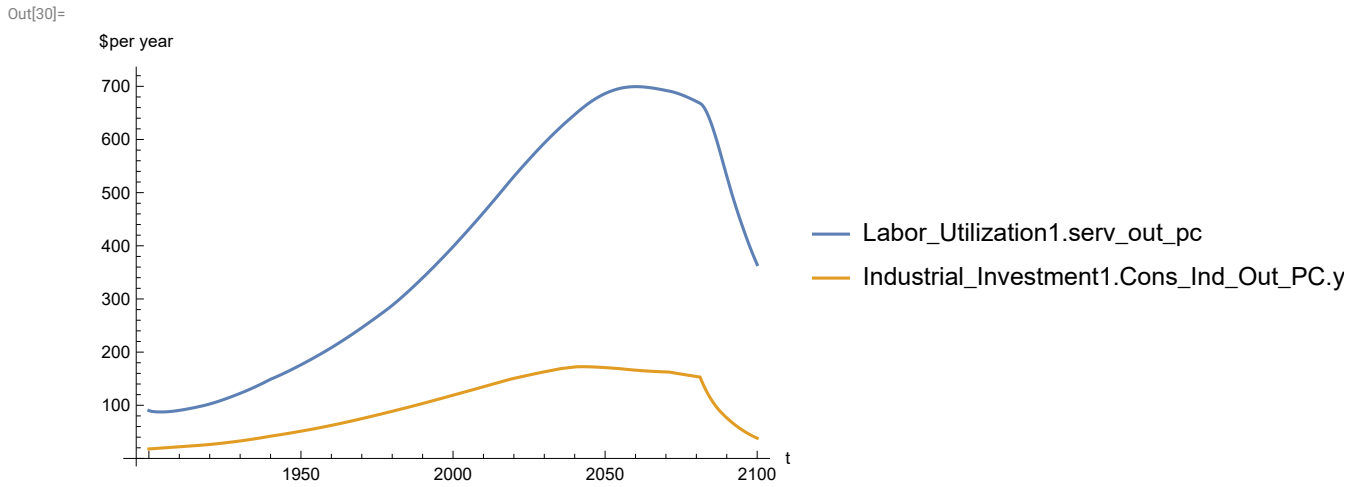
Plot total food production (kg/year), and industrial output (dollars/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

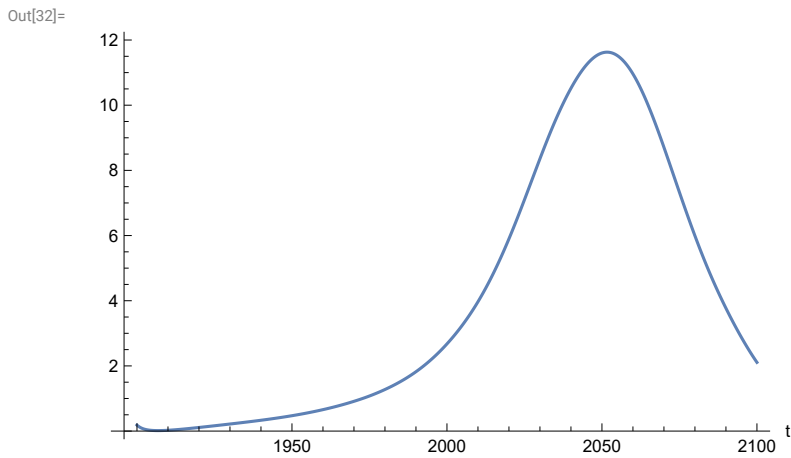


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 699.409
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



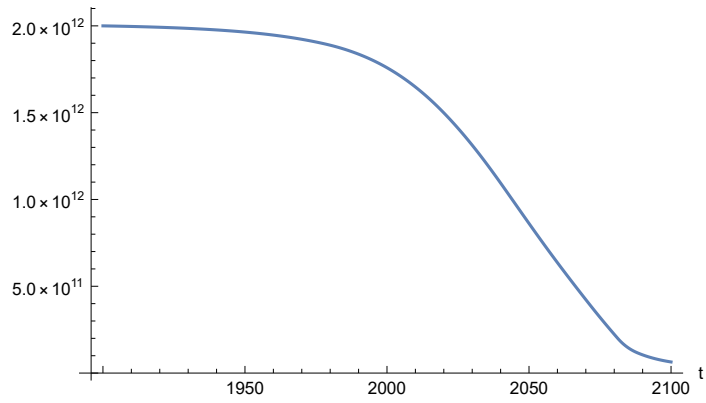
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.6272
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

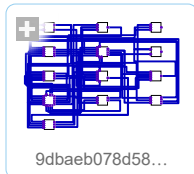


APPENDIX 3B2. LE/1.05, t_policy_year = 2002. Baseline Scenario 8, Experiment 3B2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

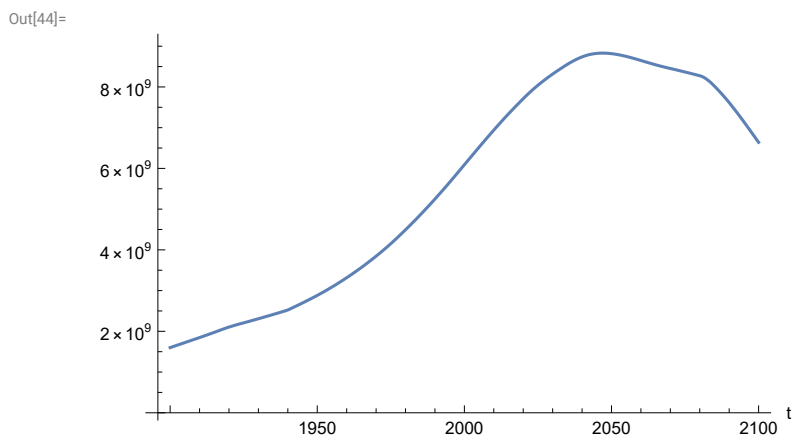
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: W9dbaeb078d58437e97f7aa369bc81fdc
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

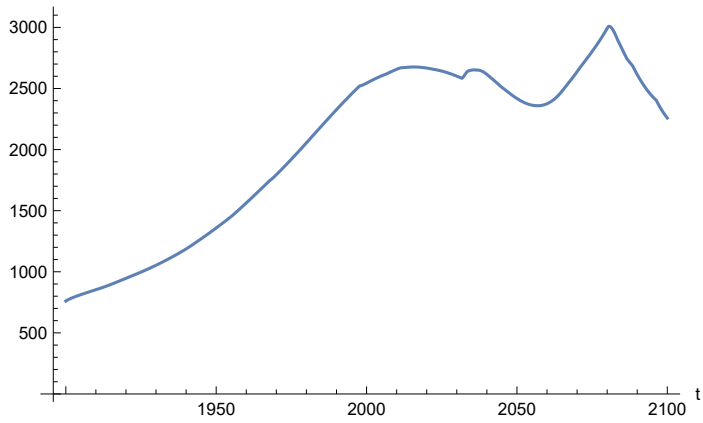
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.83067 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[46]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

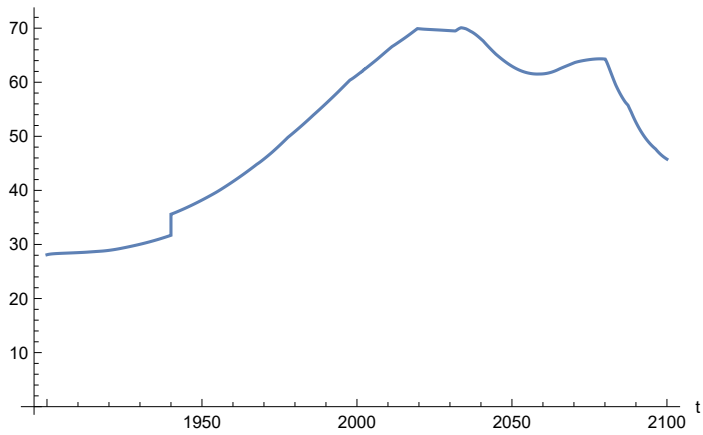
Out[46]=



Plot life expectancy, years.

In[47]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

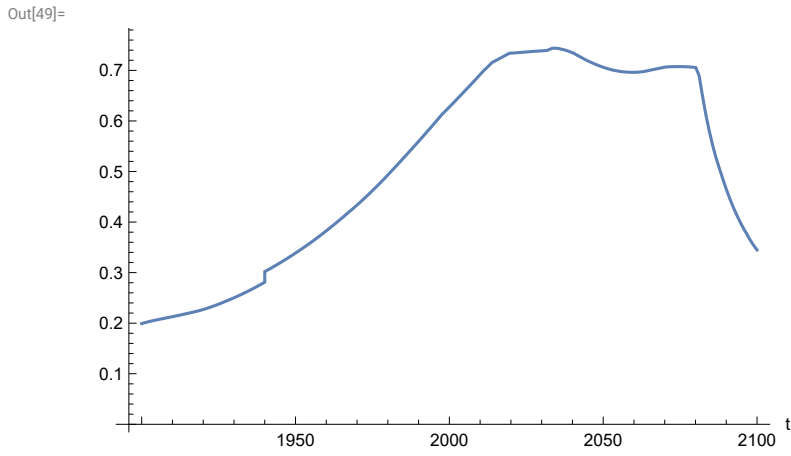
Out[47]=



In[48]:=

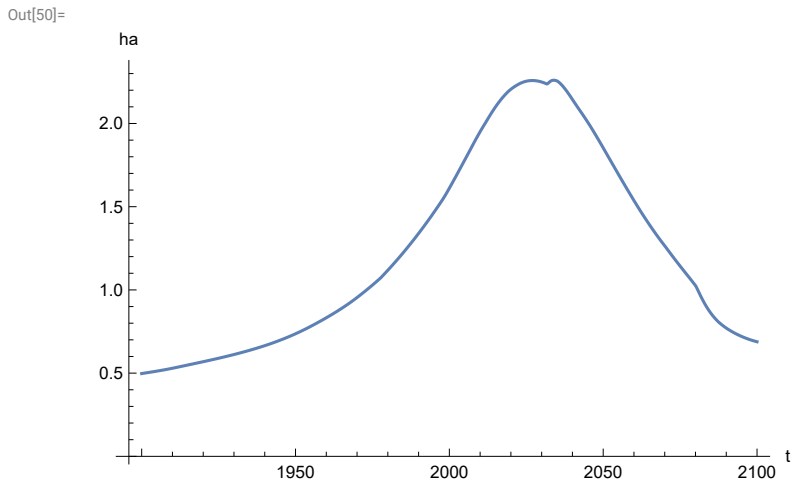
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

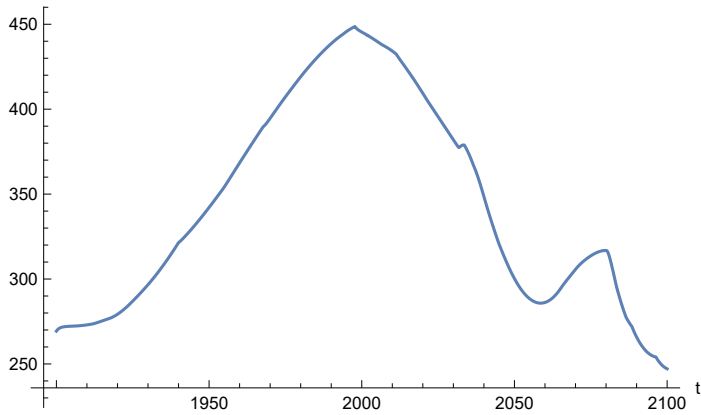
```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[51]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

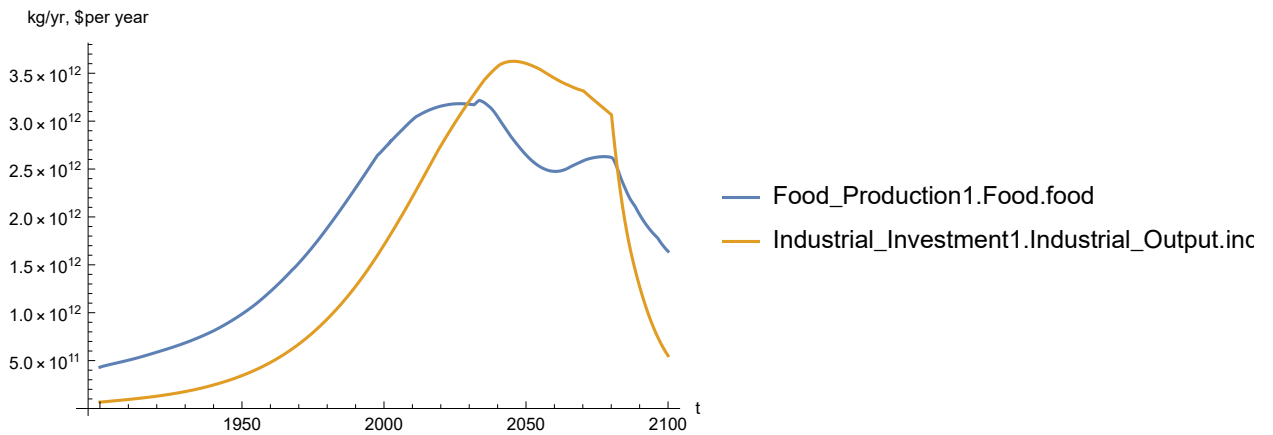
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

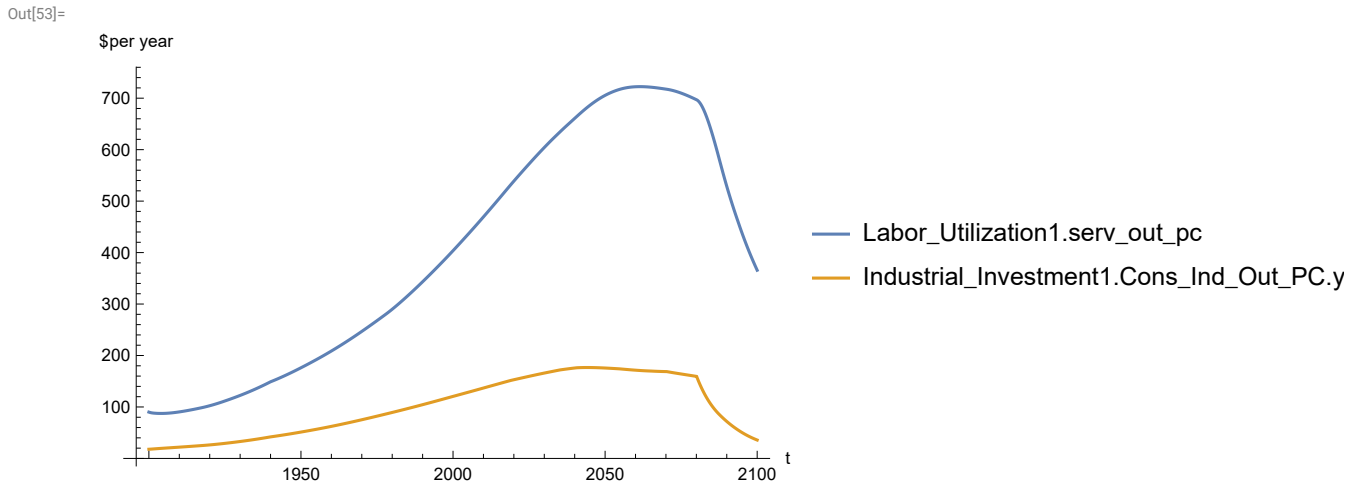
```
In[52]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

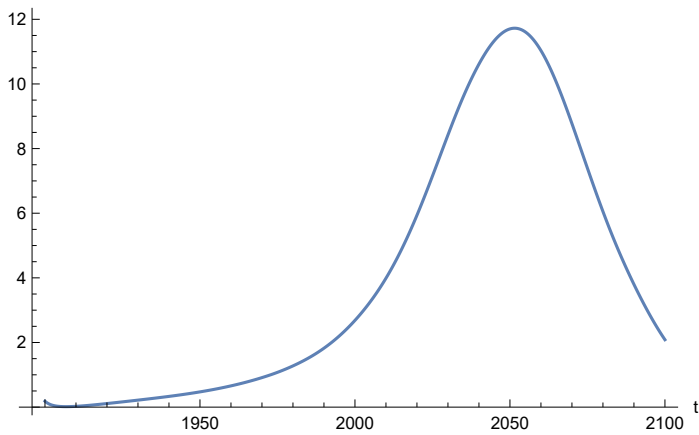


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 722.425
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



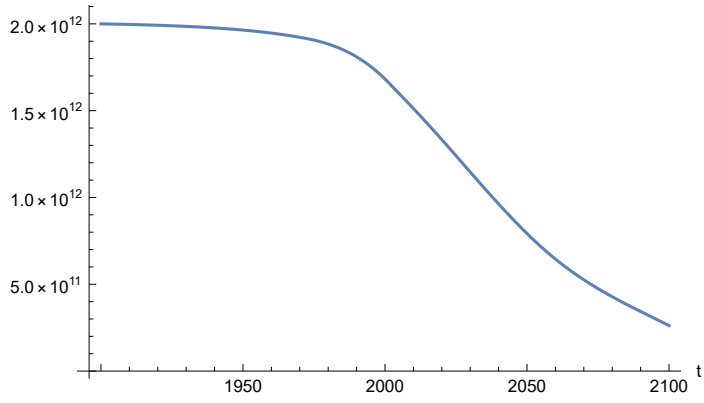
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.7244
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 3C1. BENCHMARK SCENARIO 8, Experiment 3C1. $LE = LE/1.1$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1411 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

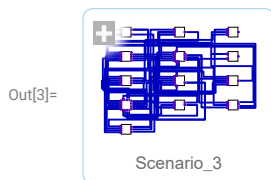
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

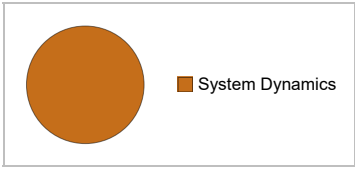
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 3.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_3"]
```



In[4]:= **mysummary = mysim["Summary"]**

	Model	SystemDynamics.WorldDynamics.World3.Scenario_3
	Description	More accessible non-recoverable natural resources and pollution control
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

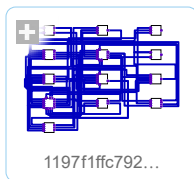
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

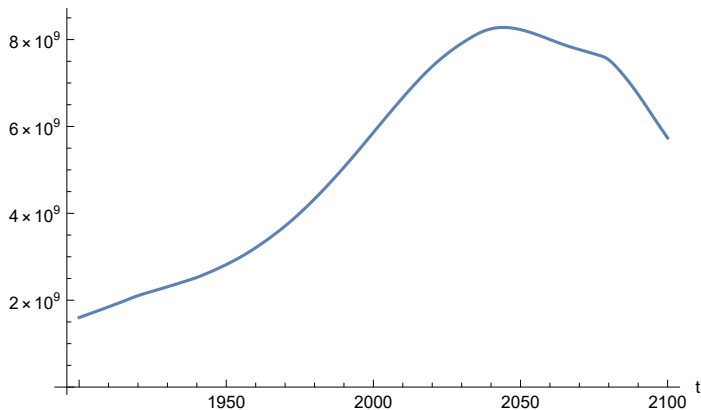
```
Out[20]=
```

```
SystemModelSimulationData [  Model: W1197f1ffc7924e6aa7a4c40a5b9893b3  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

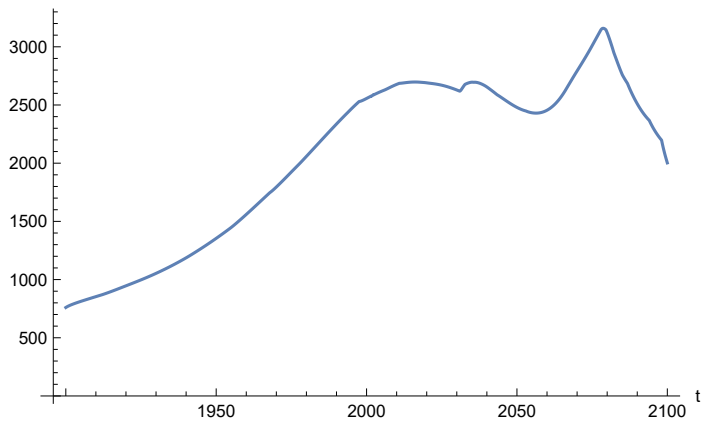
```
In[22]:= MinAndMax[basesim [{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.27981 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[23]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

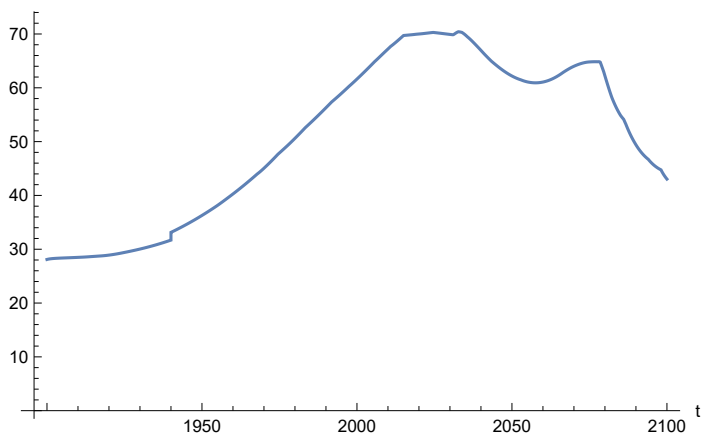
Out[23]=



Plot life expectancy, years.

```
In[24]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

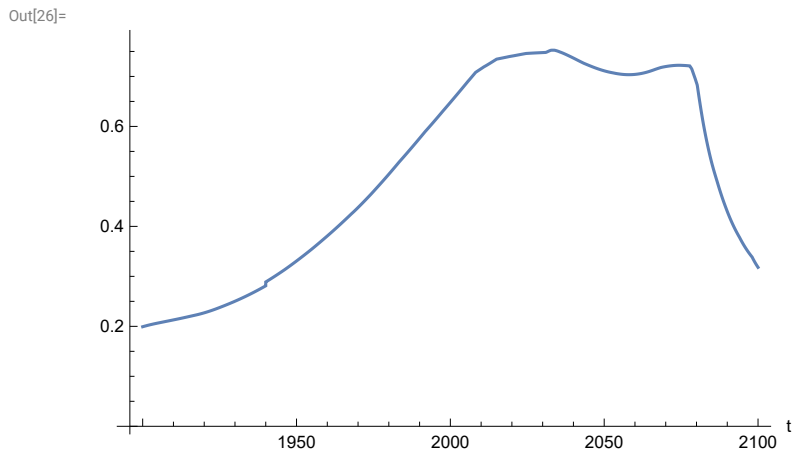
Out[24]=



In[25]=

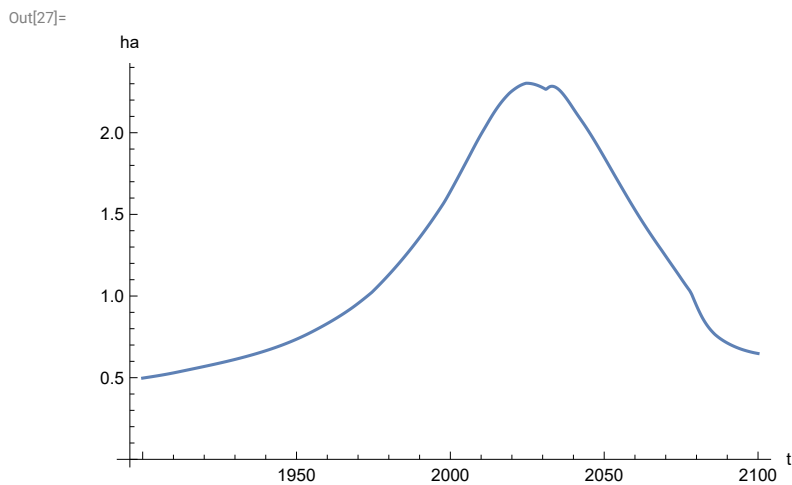
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

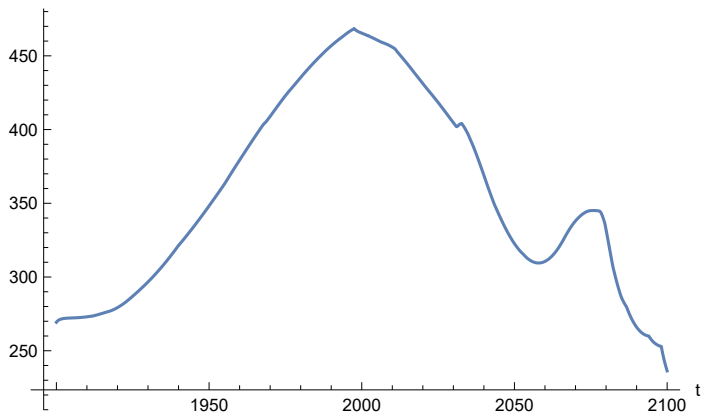
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

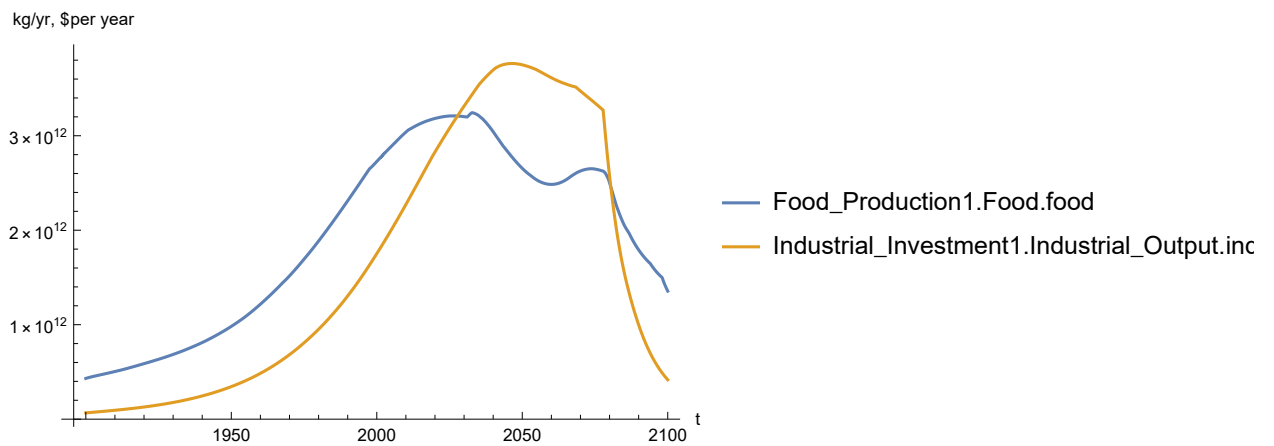
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

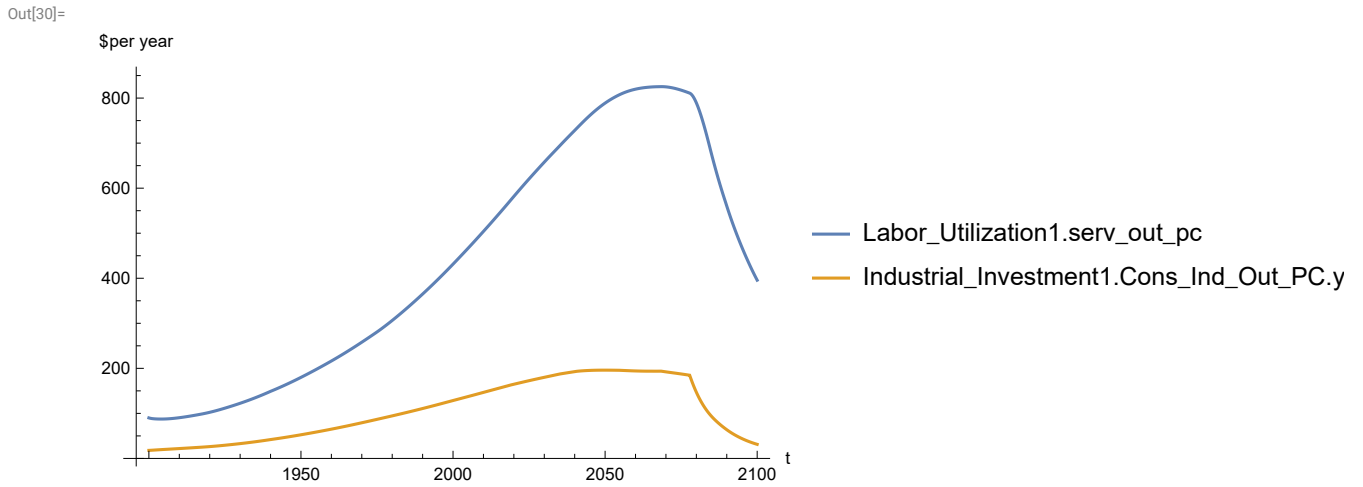
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

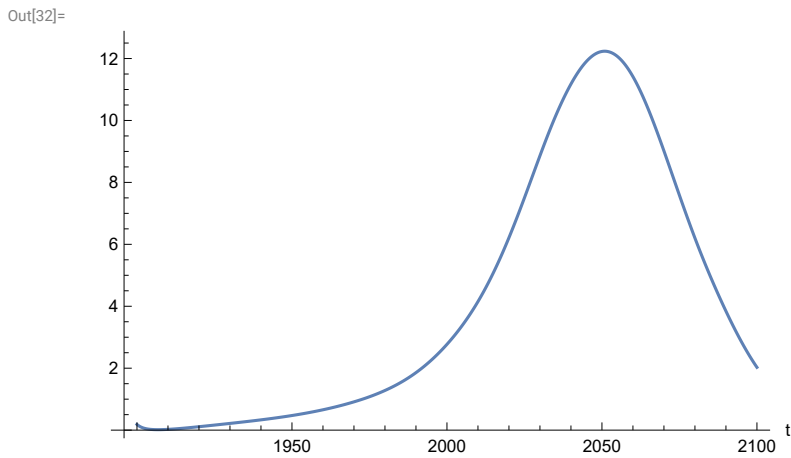


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 825.386
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

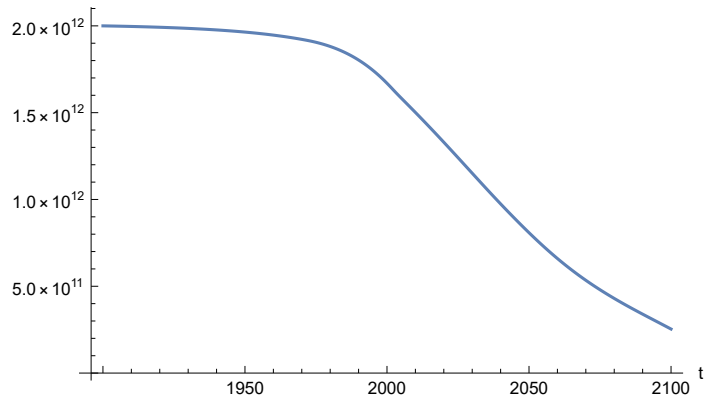


Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 12.2363
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[ ]=
```



APPENDIX 40. BENCHMARK SCENARIO 4, Experiment 40. `t_policy_year = 2002.`

Last modified: 28 July 2022/1430 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

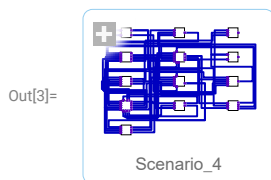
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

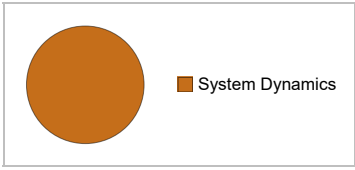
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Benchmark Scenario 4.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_4"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	M	SystemDynamics.WorldDynamics.World3.Scenario_4
	D	More accessible non-recoverable natural resources, pollution control, and land yield enhancement
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show the default value of `t_policy_year`.

```
In[5]:= SystemModel[mysim][{"ParameterValues", "t_policy_year"}]
```

```
Out[5]= {t_policy_year → 2002}
```

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

```
In[6]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[7]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[8]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[9]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute Benchmark Scenario 4 and plot various variables

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

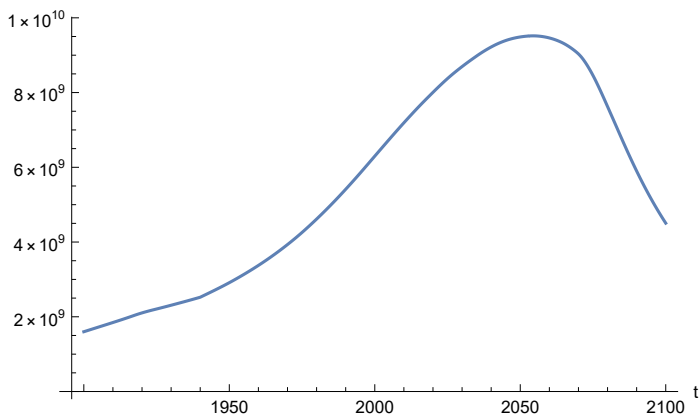
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Scenario_4
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

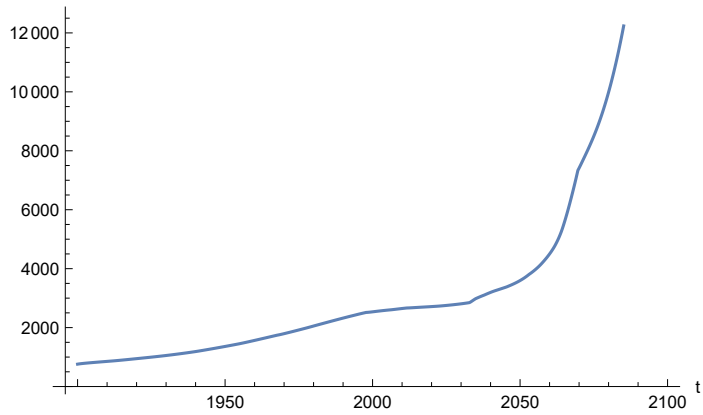
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.51746 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

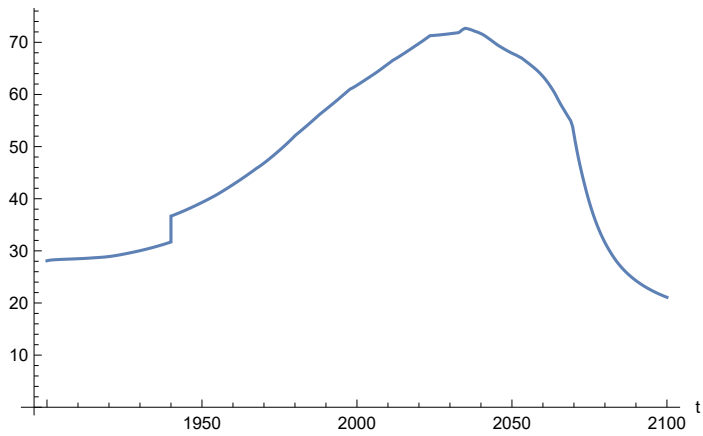
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

Out[24]=

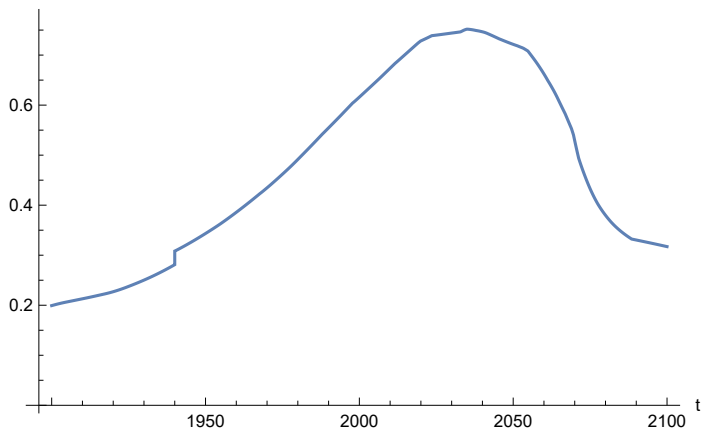


In[25]=

Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

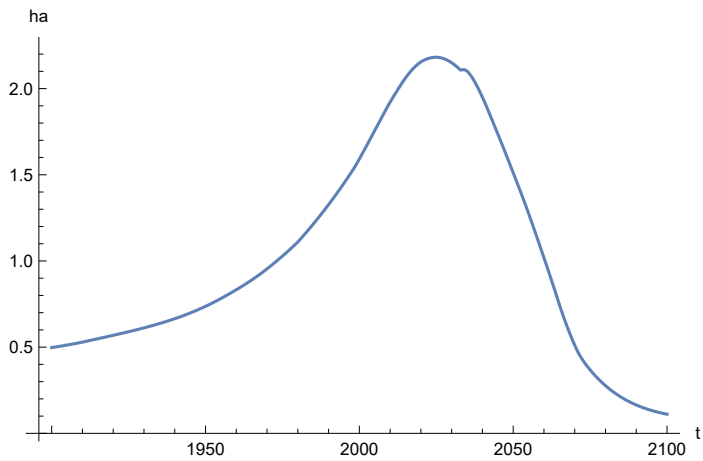
Out[26]=



Plot per capita ecological footprint, hectares.

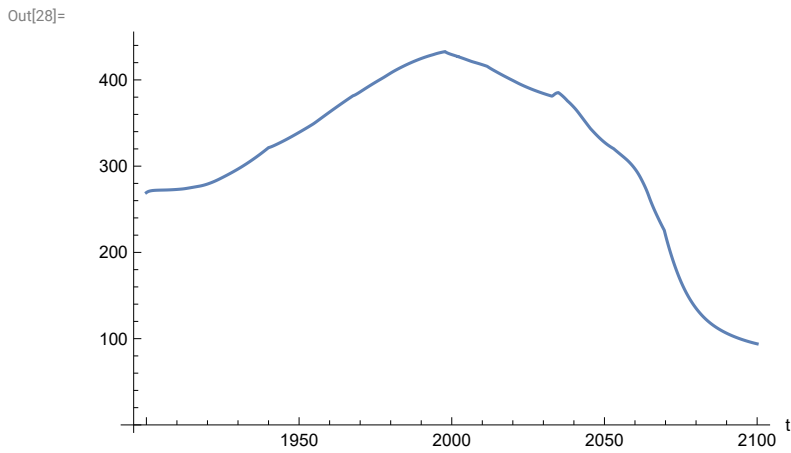
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```

Out[27]=



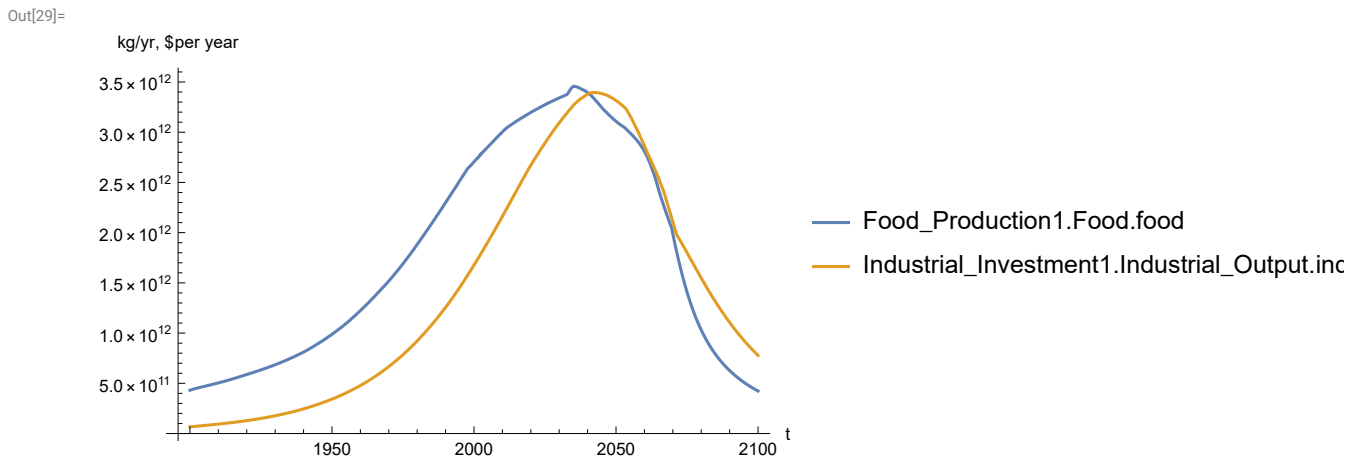
Plot food production per capita (kg/year).

```
In[28]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

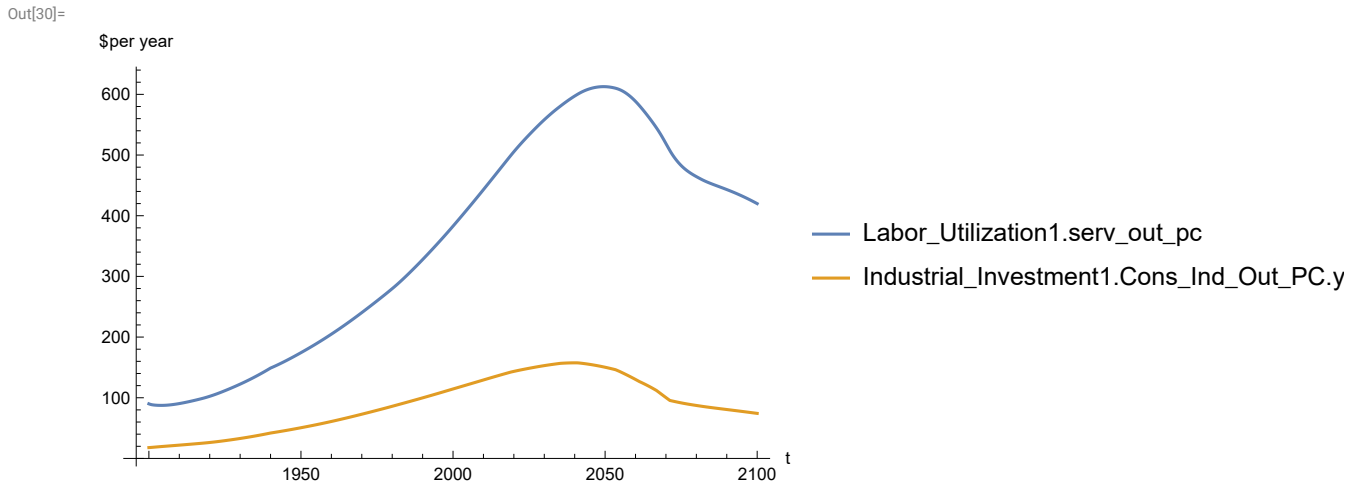
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Find max and min of y values.

Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

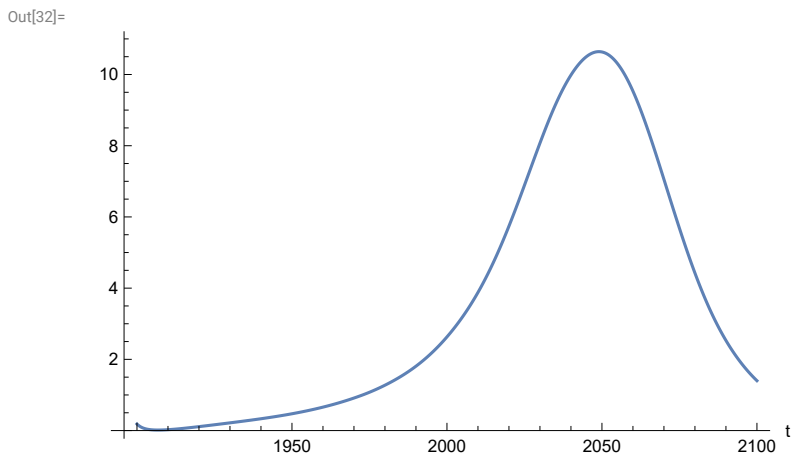
```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 612.714
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



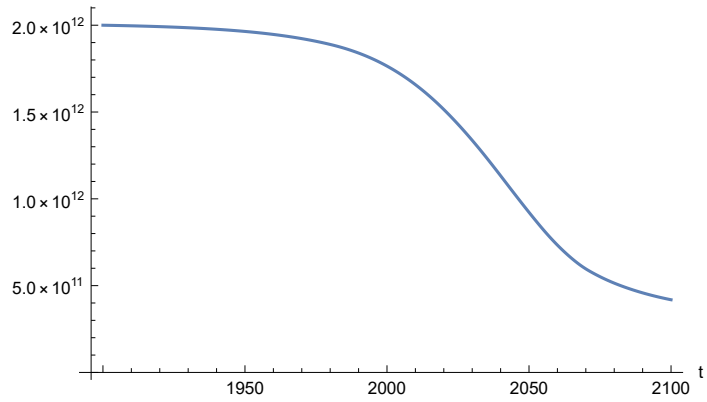
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.6416
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

```
Out[34]=
```

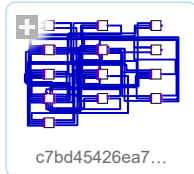


APPENDIX 41. t_policy_year = 1970, Benchmark Scenario 4, Experiment 41

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.

```
In[35]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[35]=
```



```
In[36]:= testsim1970 = SystemModelSimulate[newmysim1970]
```

```
SystemModelSimulate: At time 2079.1 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range
```

```
Out[36]=
```

```
SystemModelSimulationData [ Model: Wc7bd45426ea74573a6308f45e5cbcd27  
Time: 1.90 × 103 to 2080. ]
```

Show the value of t_policy_year.

```
In[37]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
```

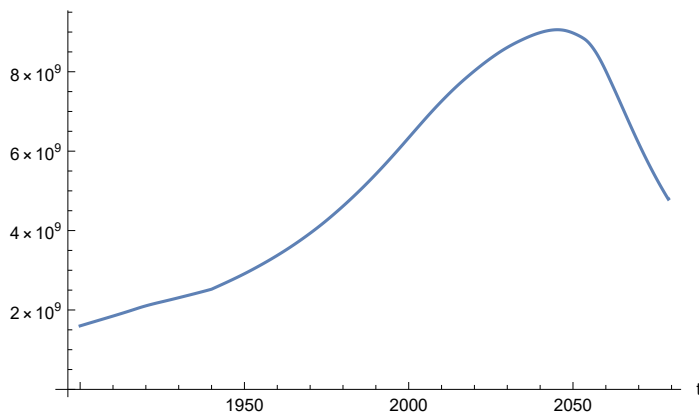
```
Out[37]=
```

```
{t_policy_year → 1970}
```

Plot the world population, people.

```
In[38]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[38]=
```



Find max and min of y values.

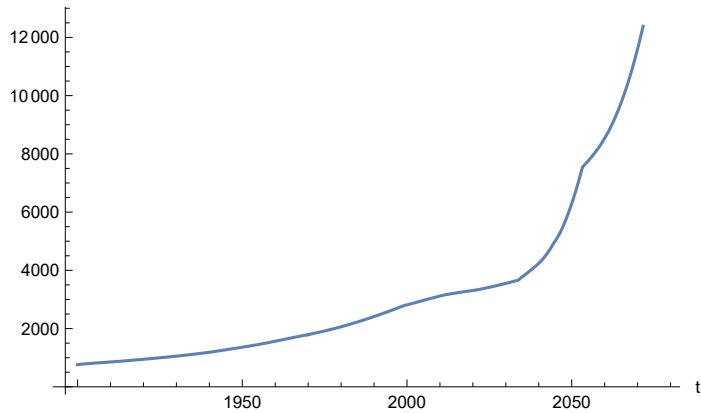
```
In[39]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 9.05861×10^9

Minimum is 1.6×10^9

```
In[40]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
```

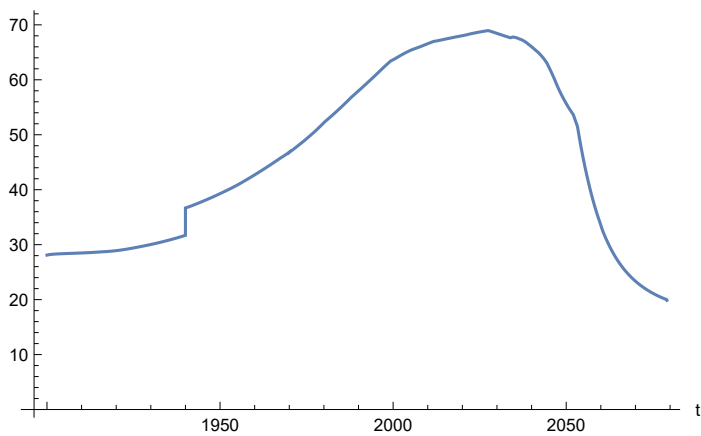
Out[40]=



Plot life expectancy, in years.

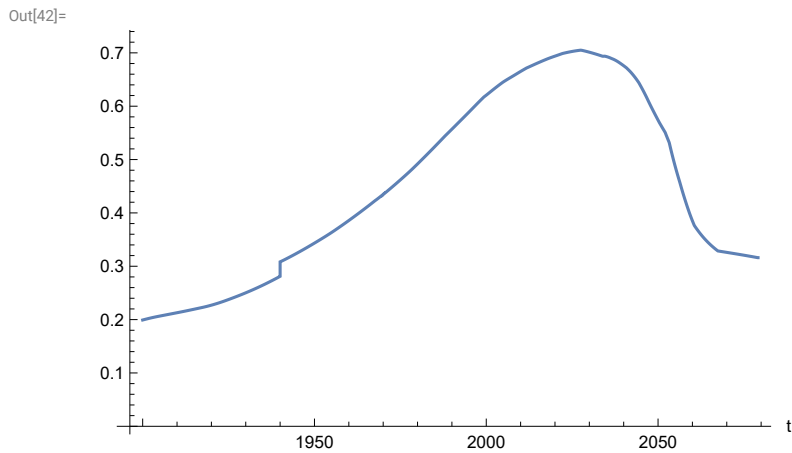
```
In[41]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[41]=



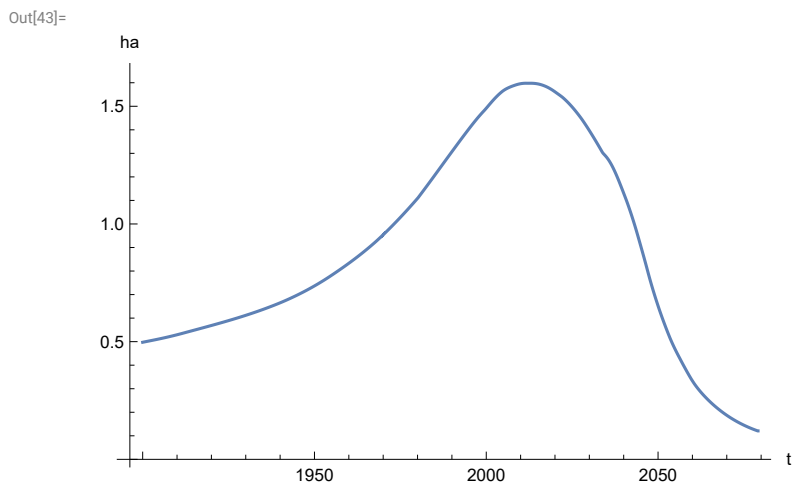
Plot the human welfare index.

```
In[42]:= SystemModelPlot[testsim1970,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



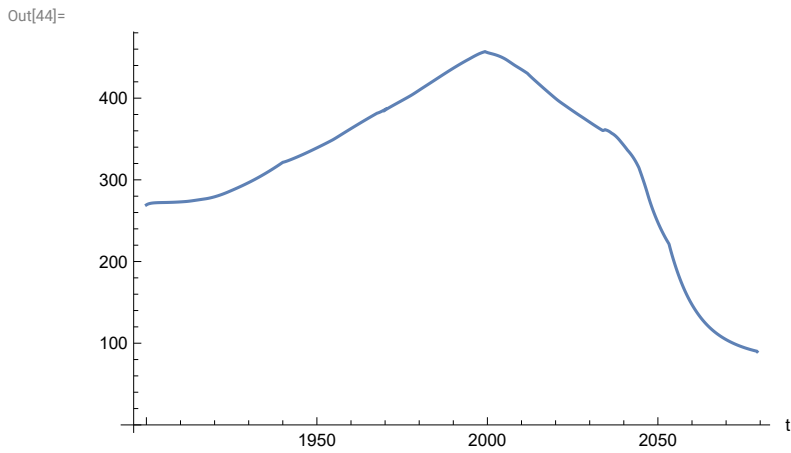
Plot the human ecological footprint, in hectares.

```
In[43]:= SystemModelPlot[testsim1970,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



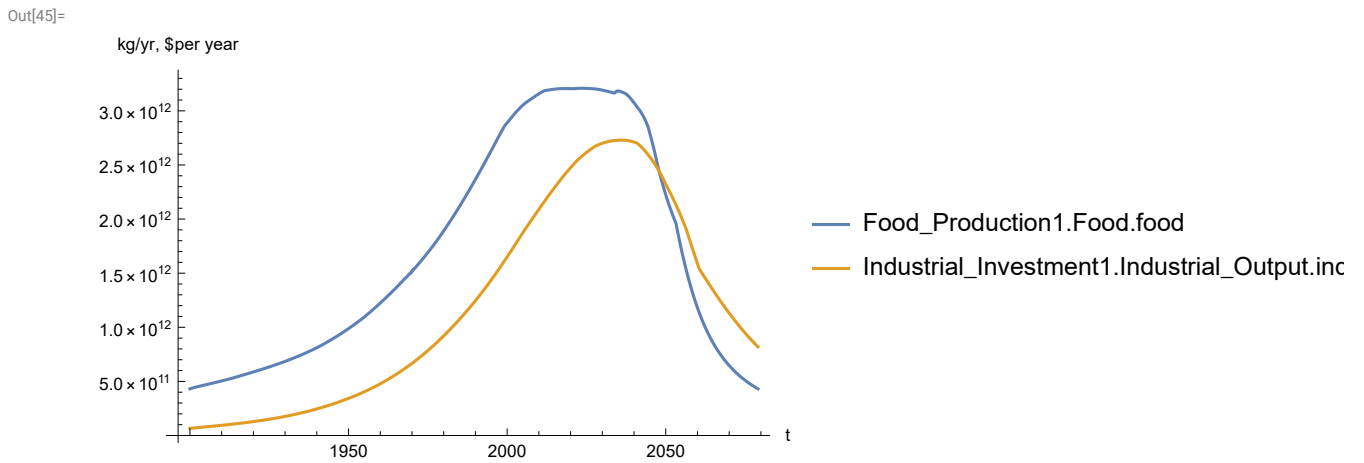
Plot per capita food production, kg/year.

```
In[44]:= SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/yr) and industrial output (in dollars).

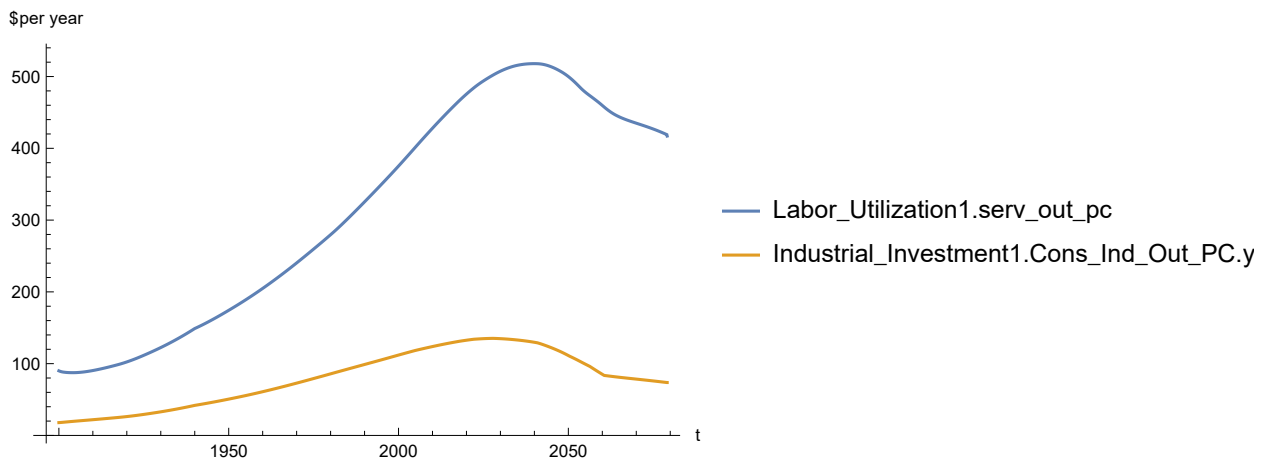
```
In[45]:= SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[46]:= SystemModelPlot[testsim1970,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[46]=



Find max and min of y values.

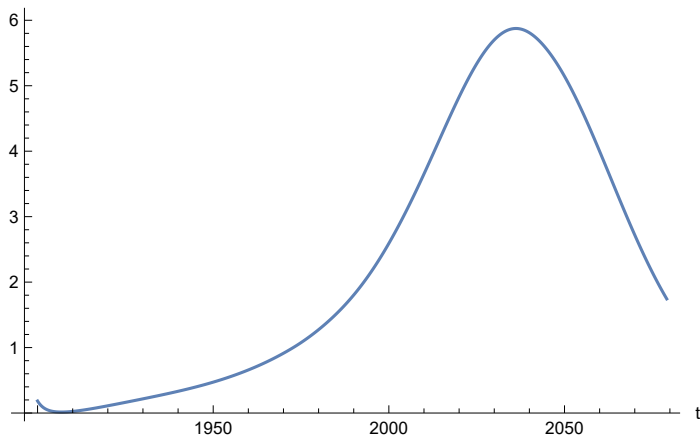
```
In[47]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 517.966
 Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[48]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[48]=



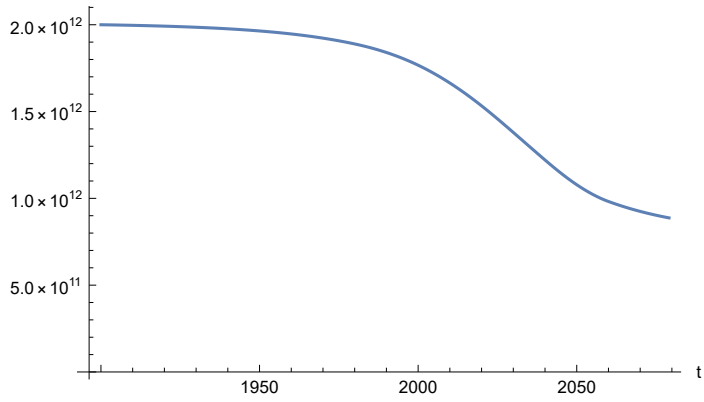
Find max and min of y values.

```
In[49]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 5.8746
 Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[50]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[50]=
```

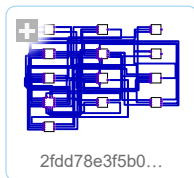


APPENDIX 42. Benchmark Scenario 4, $t_{\text{policy_year}} = 2025$. Experiment 42.

Change the value of the air pollution effect multiplier switch time $t_{\text{policy_year}}$, to calendar year 2025, and execute the resulting scenario, plotting various variables..

```
In[51]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```

```
Out[51]=
```



```
In[52]:= testsim = SystemModelSimulate[newmysim]
```

```
Out[52]=
```

```
SystemModelSimulationData [ { Model: W2fdd78e3f5b048bfd5e829b4f562d68  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  } ]
```

Show the value of $t_{\text{policy_year}}$.

```
In[53]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
```

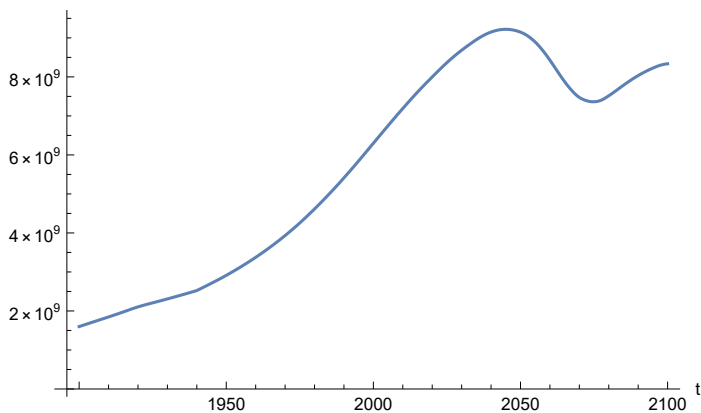
```
Out[53]=
```

```
{t_policy_year → 2025}
```

Plot the world population, people.

```
In[54]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[54]=
```

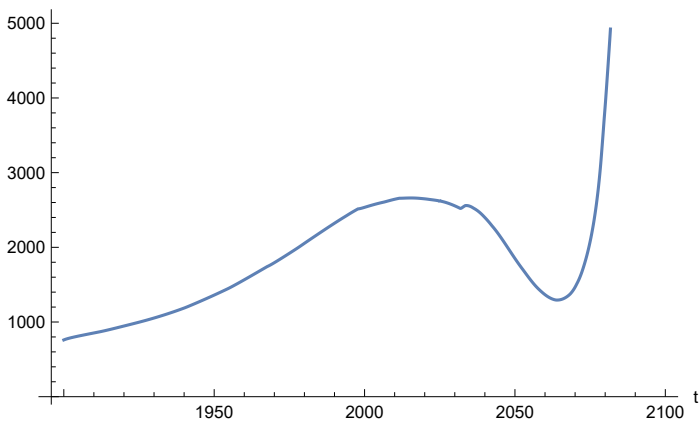


Find max and min of y values.

```
In[55]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.21937 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

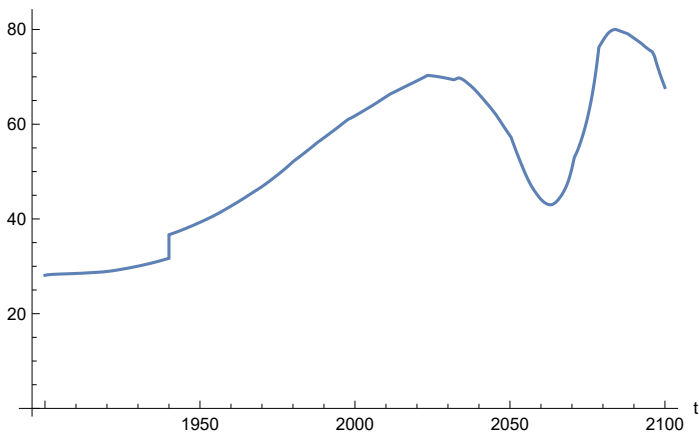
Plot land yield.

```
In[56]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[56]=
```



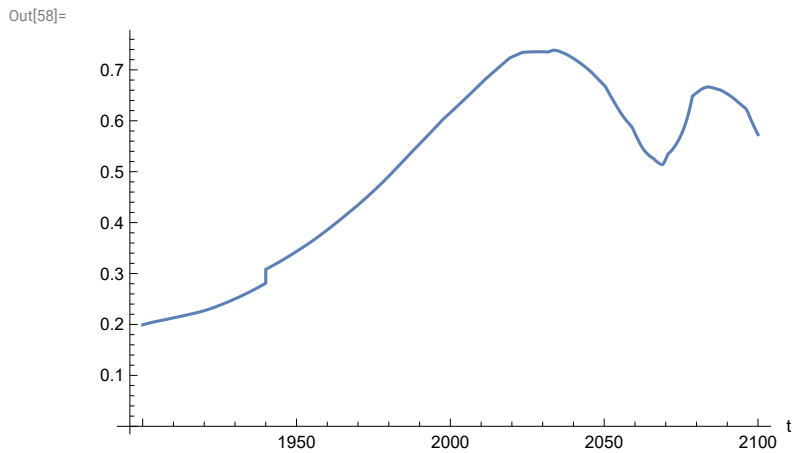
Plot life expectancy, in years.

```
In[57]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[57]=
```



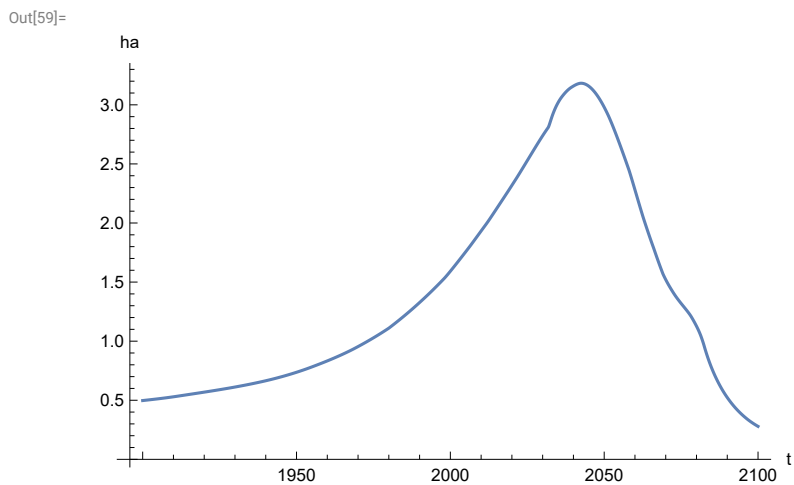
Plot the human welfare index.

```
In[58]:= SystemModelPlot[testsim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot the human ecological footprint, in hectares.

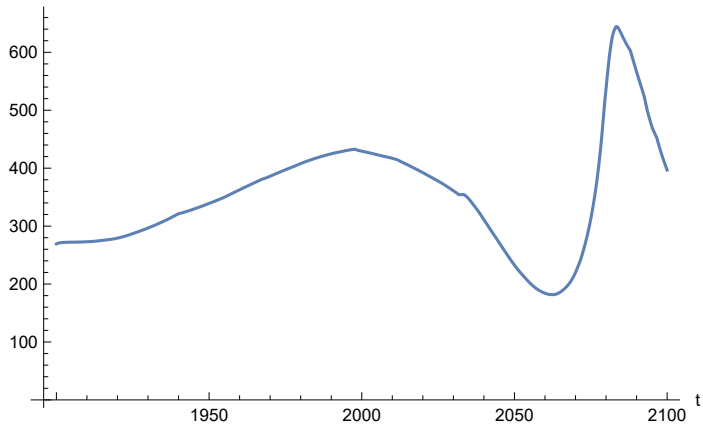
```
In[59]:= SystemModelPlot[testsim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
 _footprint"}]
```



Plot per capita food production, kg/year.

In[60]:= **SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]**

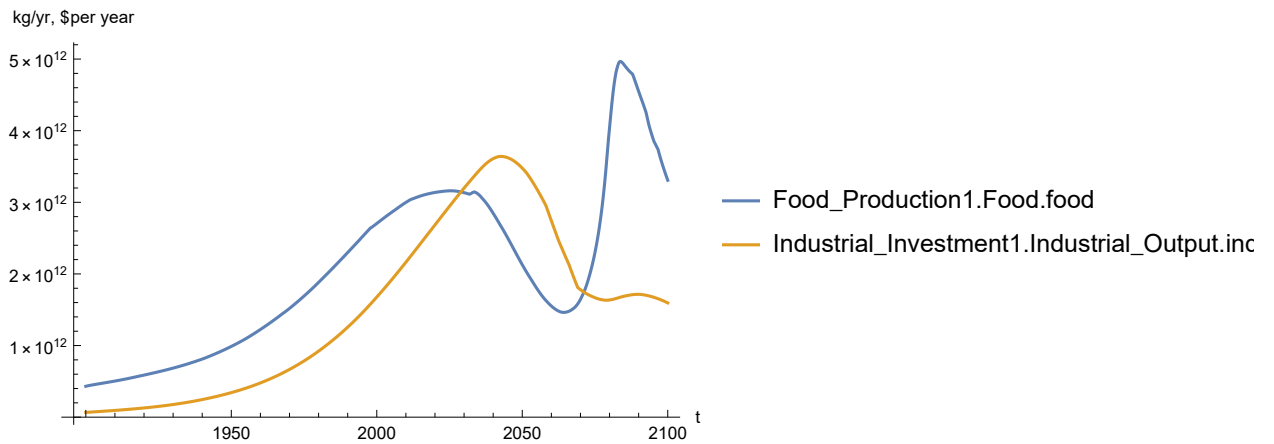
Out[60]=



Plot total food production (kg/yr) and industrial output (in dollars).

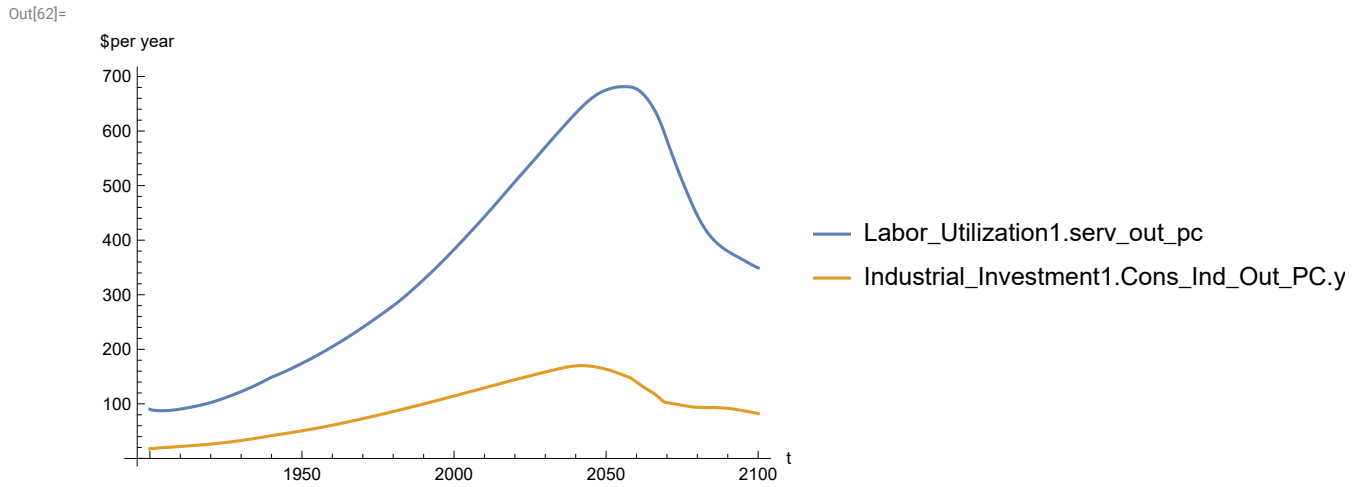
In[61]:= **SystemModelPlot[testsim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[61]=



Plot consolidated industrial output per capita (dollars/year).

```
In[62]:= SystemModelPlot[testsim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

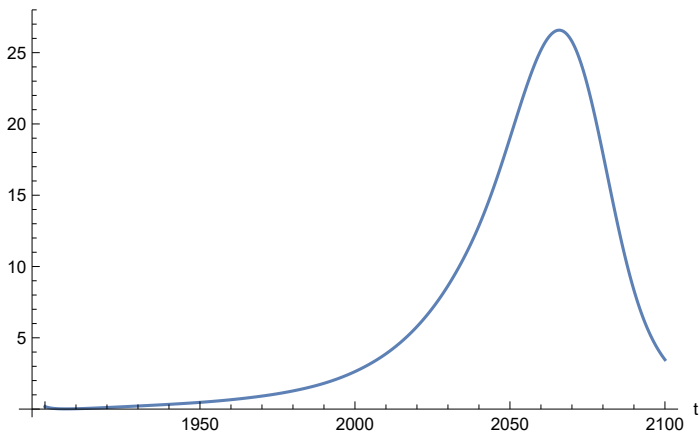


Find max and min of y values.

```
In[63]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 681.407
Minimum is 87.4451
```

Plot persistent pollution index (normalized to 1970 value).

```
In[64]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[64]=
```

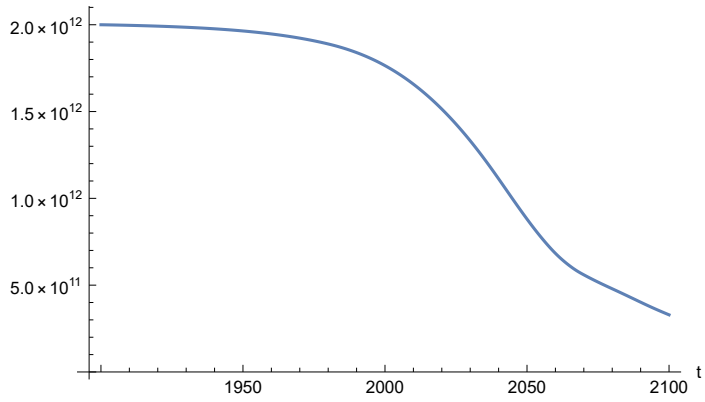


Find max and min of y values.

```
In[65]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 26.5762
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[66]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[66]=
```



APPENDIX 43. BENCHMARK SCENARIO 4, Experiment 43. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 28 July 2022/1450 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

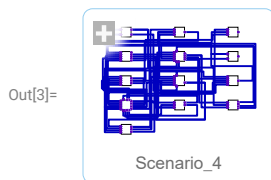
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

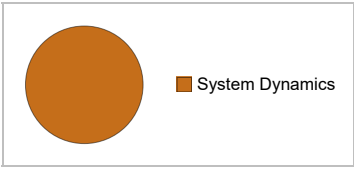
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 4.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_4"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	M	SystemDynamics.WorldDynamics.World3.Scenario_4
	D	More accessible non-recoverable natural resources, pollution control, and land yield enhancement
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

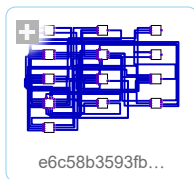
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

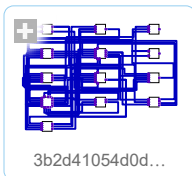
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```




Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

SystemModelSimulate: At time 2079.1 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

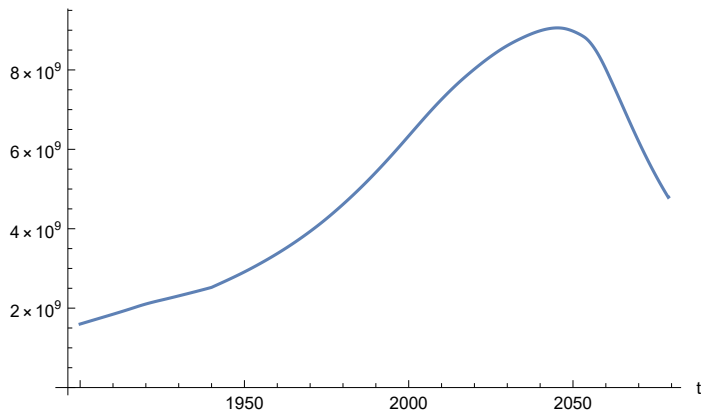
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W3b2d41054d0d43f9acdd2946d0741981  
Time: 1.90 × 103 to 2080. ]
```

Plot total population, people.

In[22]:= **SystemModelPlot**[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]

Out[22]=



Find max and min of population values.

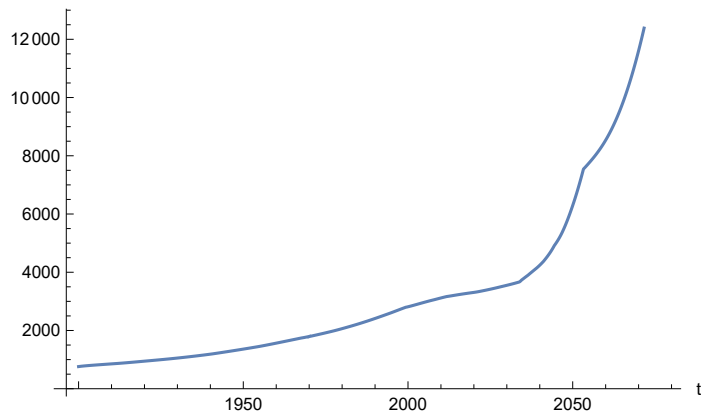
In[23]:= **MinAndMax**[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]

Maximum is 9.05861×10^9

Minimum is 1.6×10^9

In[24]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

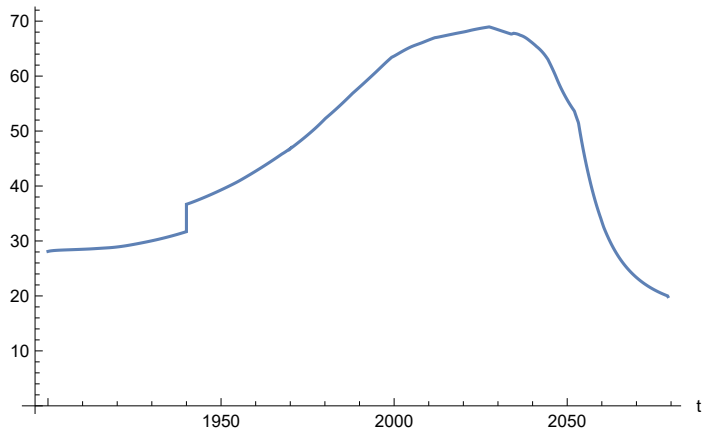
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[25]=

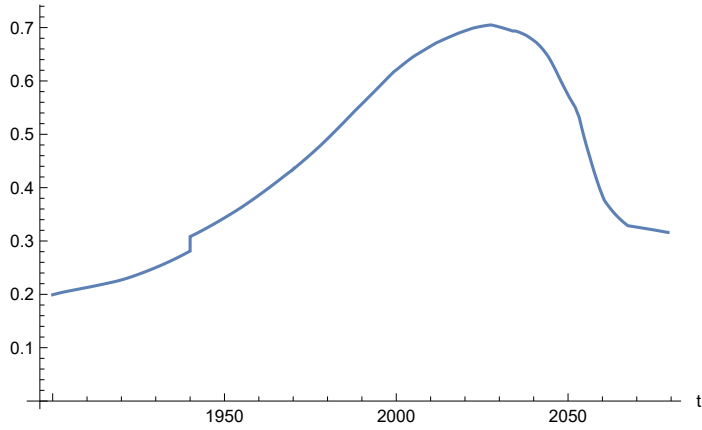


In[26]:=

Plot human welfare index.

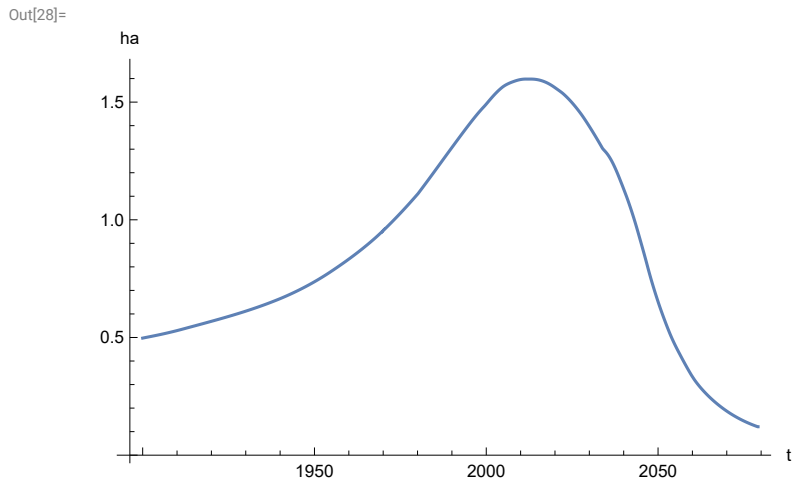
```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

Out[27]=



Plot per capita ecological footprint, hectares.

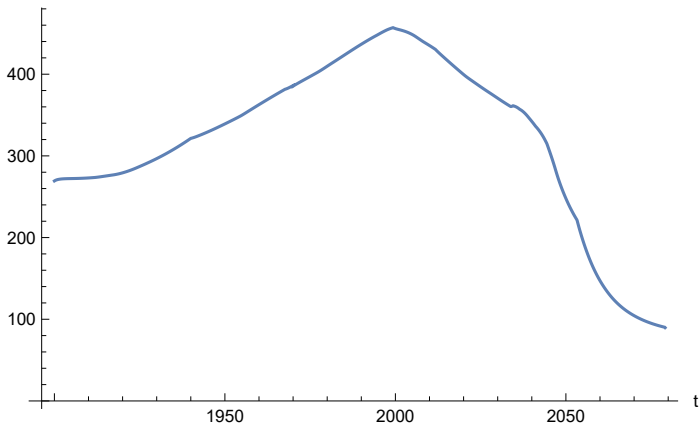
```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[29]=

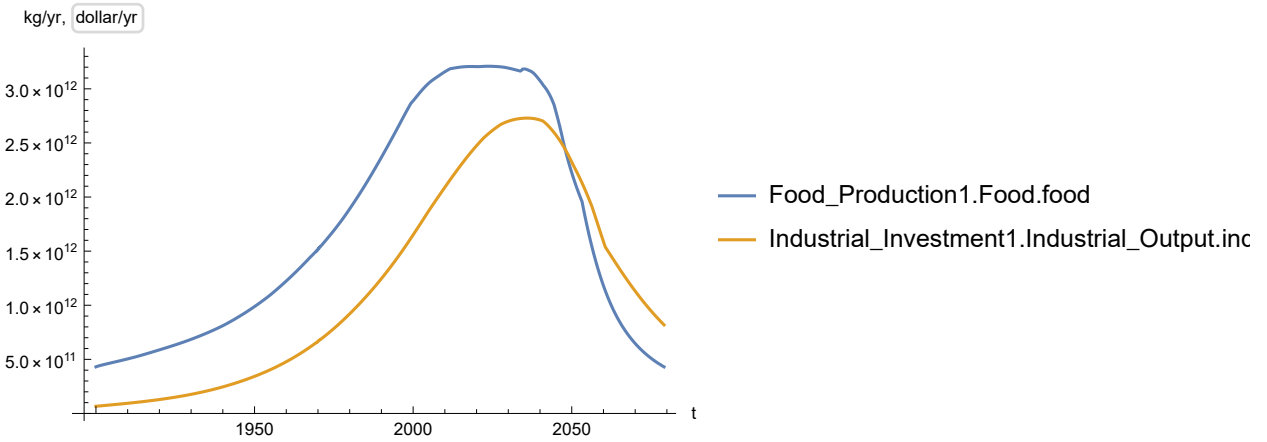


Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Quantity: A network operation for Quantity timed out. Please try again later.

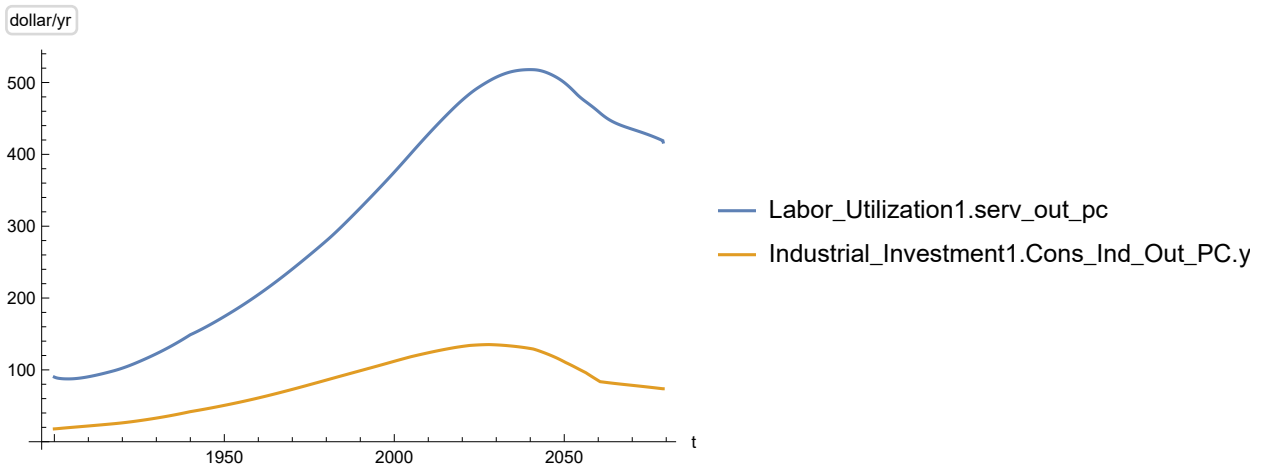
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
    {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

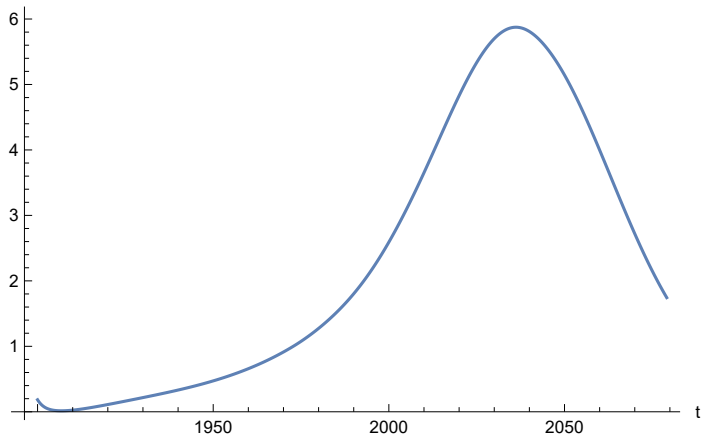
Maximum is 517.966

Minimum is 87.4451

Plot persistent pollution index.

In[33]:= **SystemModelPlot**[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]

Out[33]=



Find max and min of y values.

In[34]:= **MinAndMax**[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]

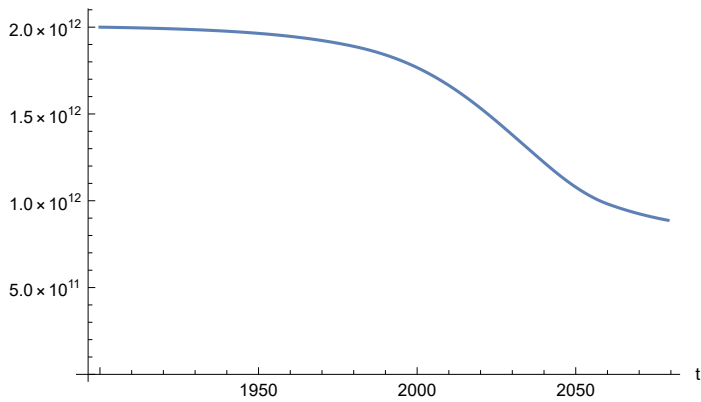
Maximum is 5.8746

Minimum is 0.0150765

Plot non-renewable resources remaining.

In[35]:= **SystemModelPlot**[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]

Out[35]=

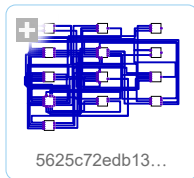


APPENDIX 44. LE/1.001, t_policy_year = 2025. Baseline Scenario 4, Experiment 44.

Set `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals` to LE/1.001. Note: this particular divisor does not change the two-significant-figure default `_Serv_2.y_vals`

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[36]=



Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals`.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

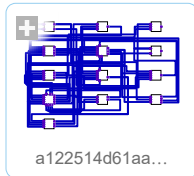
```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```


```
Out[44]=
```



Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

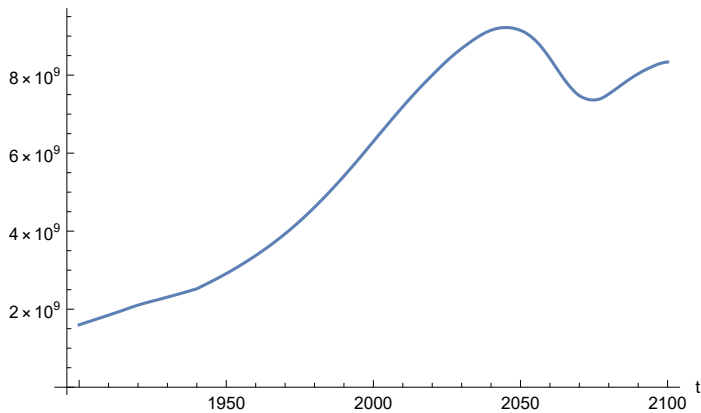
```
Out[45]=
```

```
SystemModelSimulationData [  Model: Wa122514d61aa4c9ea2dd509621a76197  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[46]=
```



Find max and min of population values.

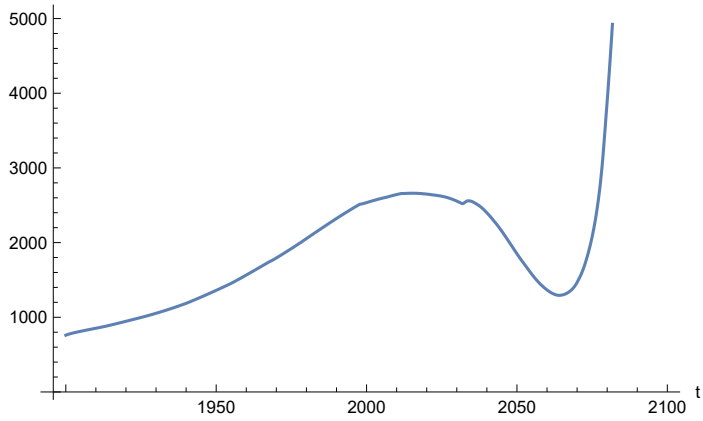
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.21937 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

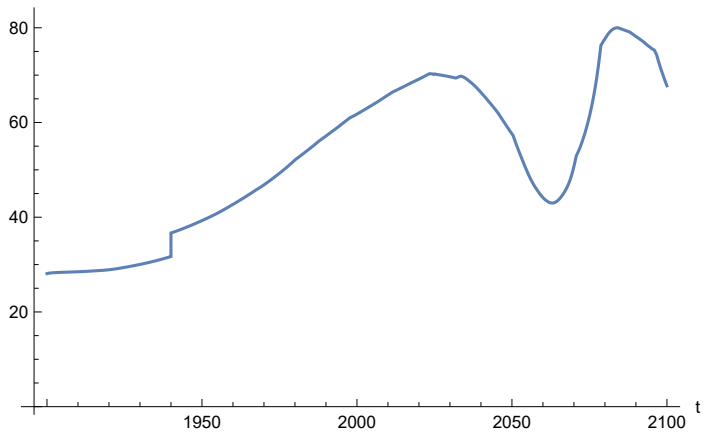
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

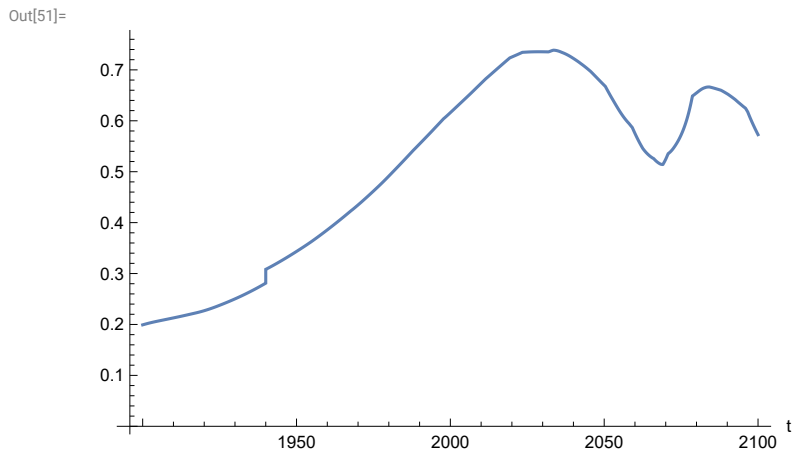
Out[49]=



In[50]:=

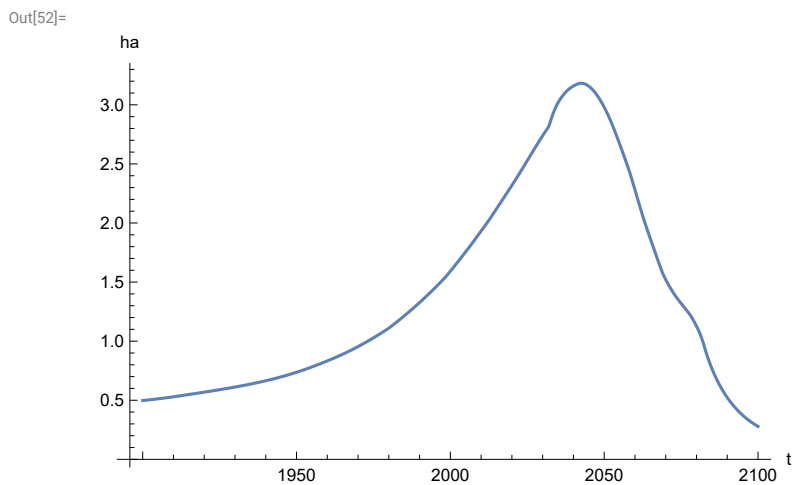
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HEF_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

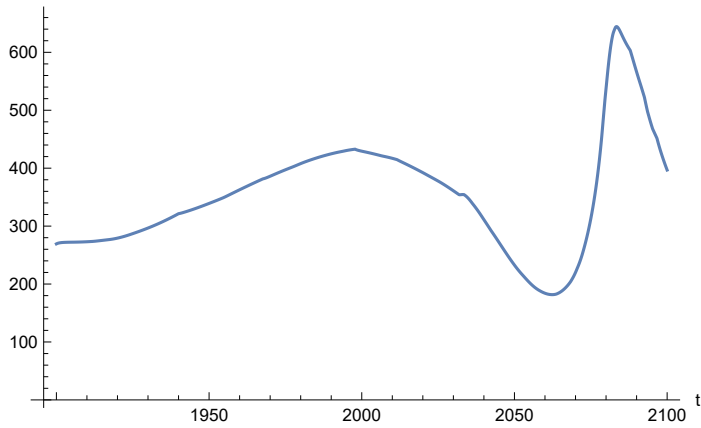
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

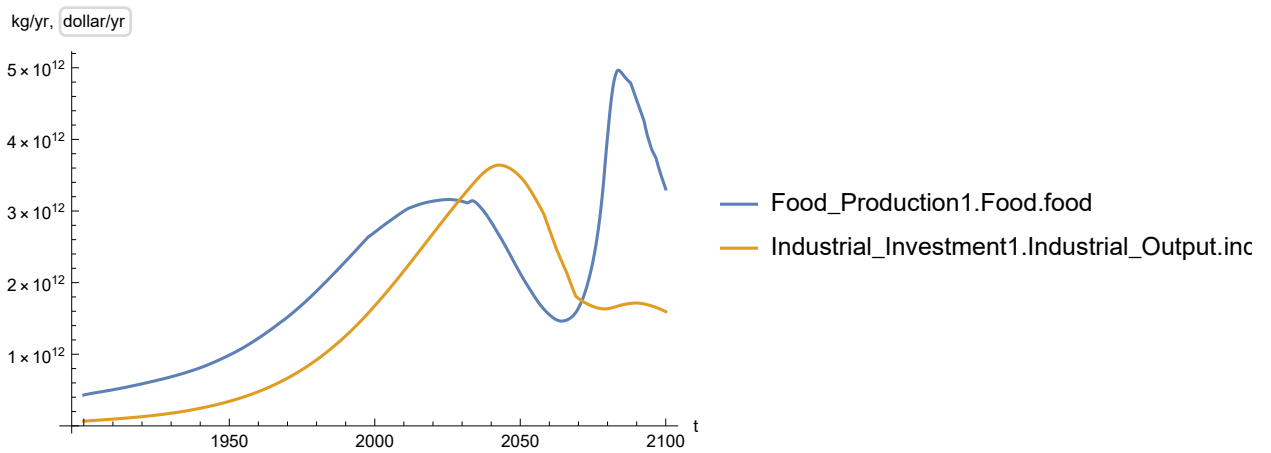
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

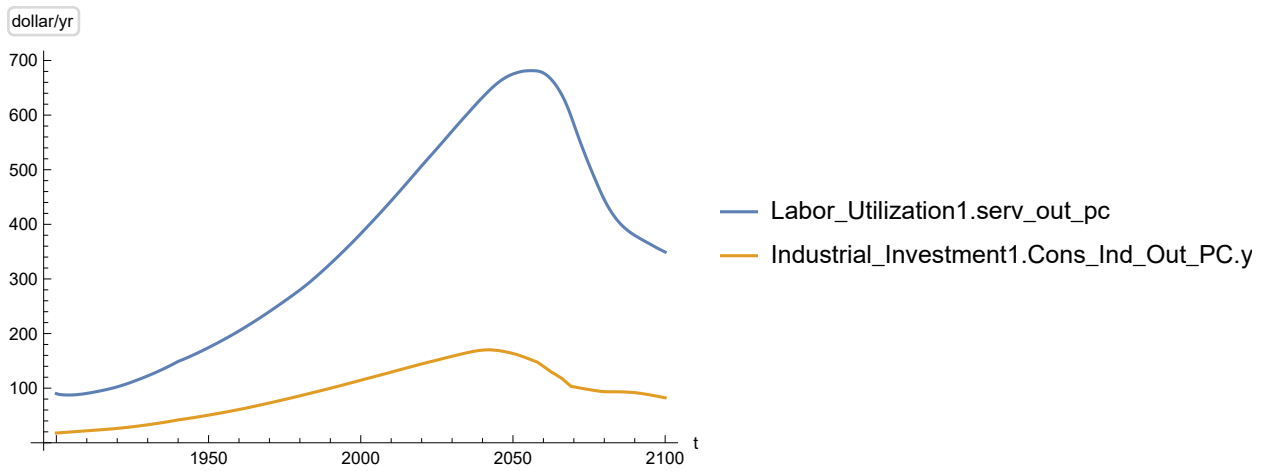
Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[55]=



Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

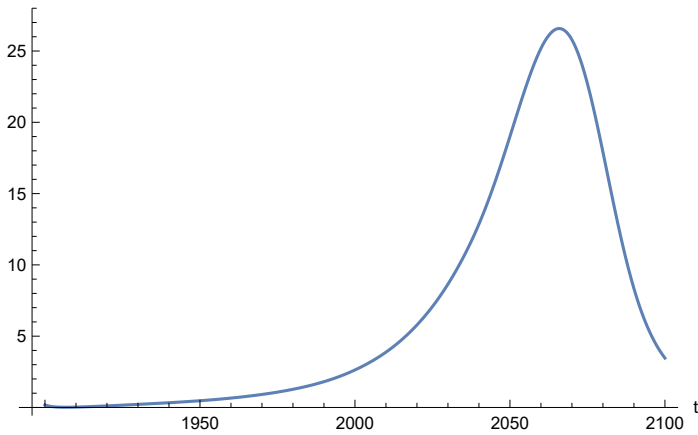
Maximum is 681.407

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[57]=



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

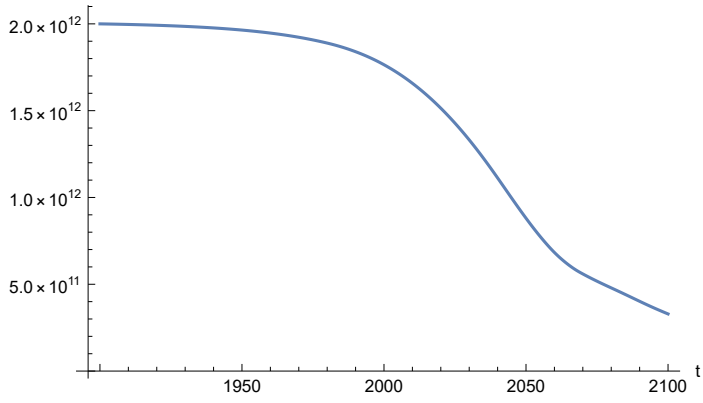
Maximum is 26.5762

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

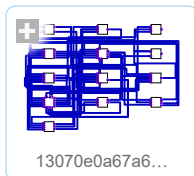


APPENDIX 45. LE/1.01, t_policy_year = 1970. Baseline Scenario 4, Experiment 45.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

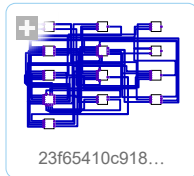
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

```
SystemModelSimulate: At time 2079.1 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range
```

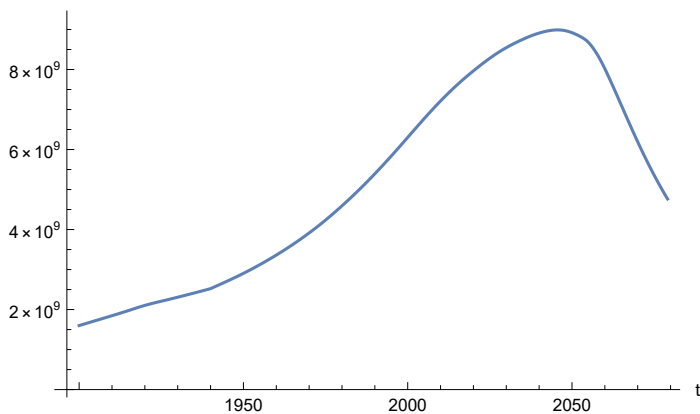
```
Out[69]=
```

```
SystemModelSimulationData [
  Model: W23f65410c918438dbae4c488f2306e46
  Time: 1.90 × 103 to 2080.
]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```

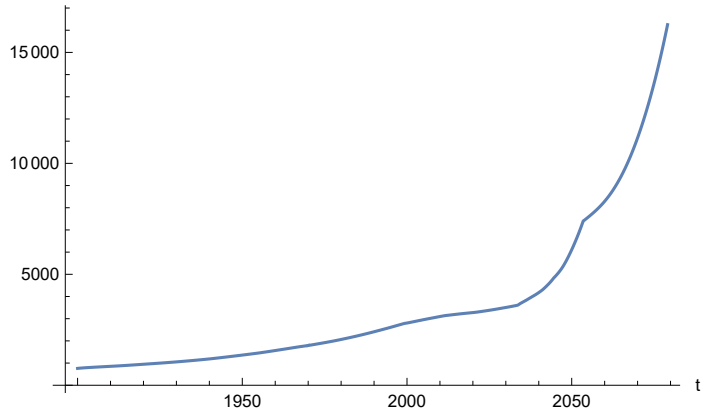


Find max and min of population values.

```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

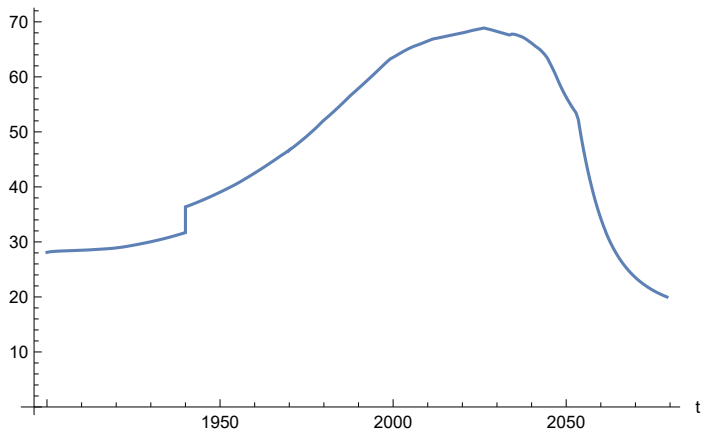
Maximum is 8.99005×10^9
 Minimum is 1.6×10^9

```
In[72]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[72]=
```



Plot life expectancy, years.

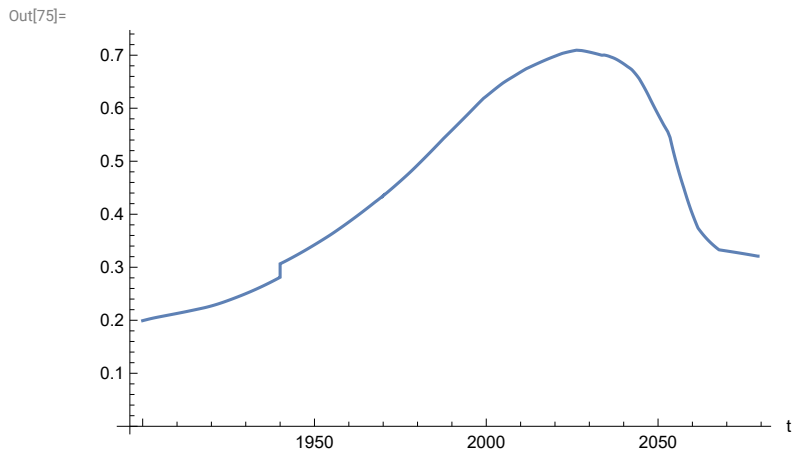
```
In[73]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[73]=
```



```
In[74]:=
```

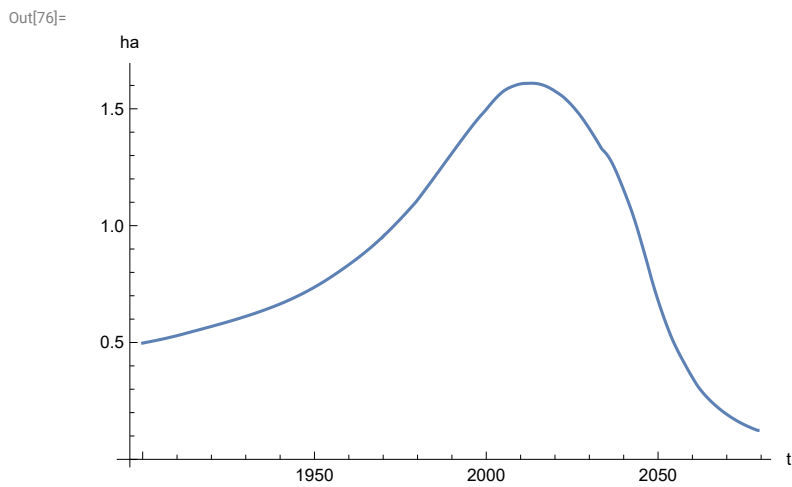
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

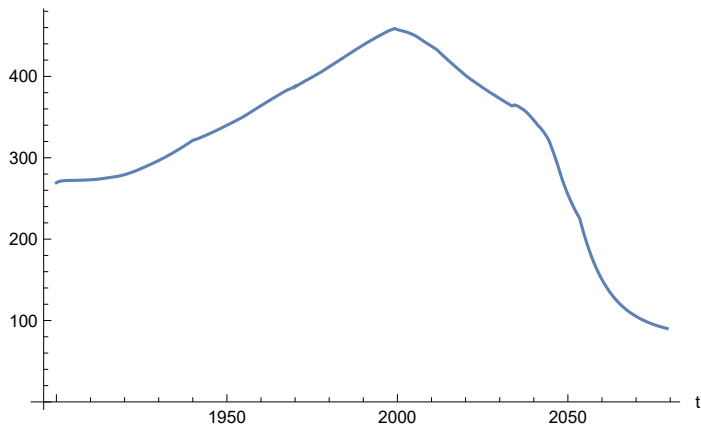
```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

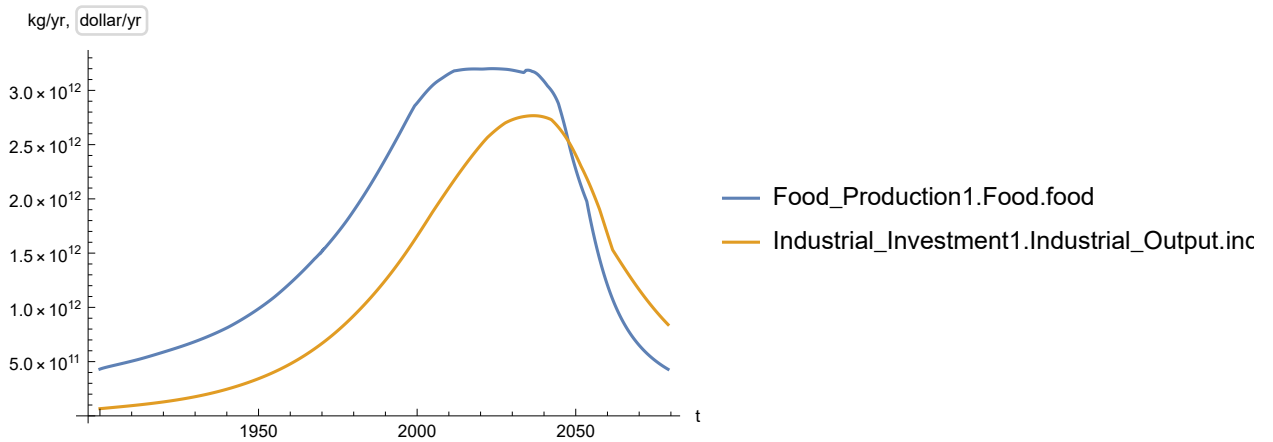
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

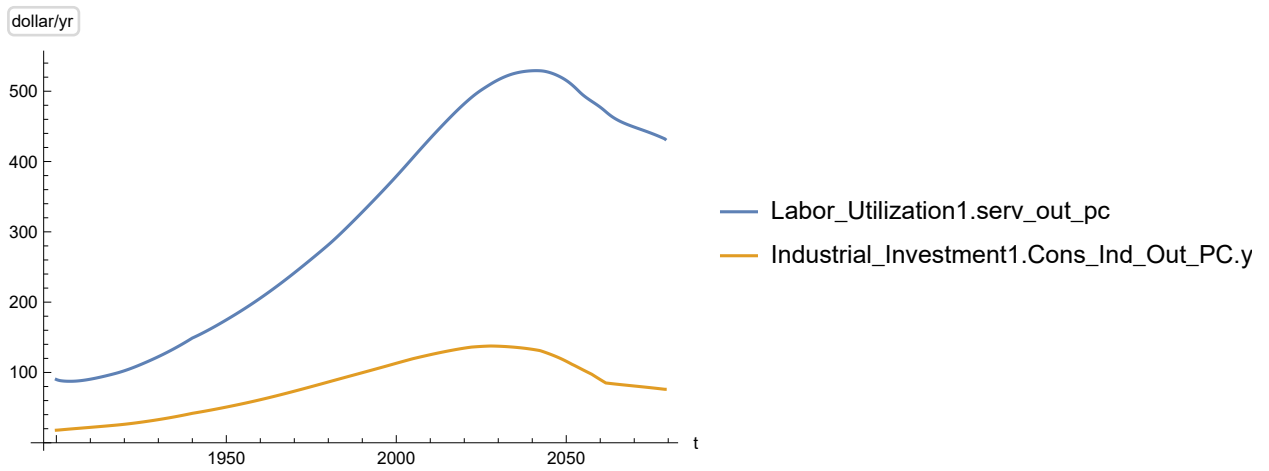
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

```
Out[79]=
```



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

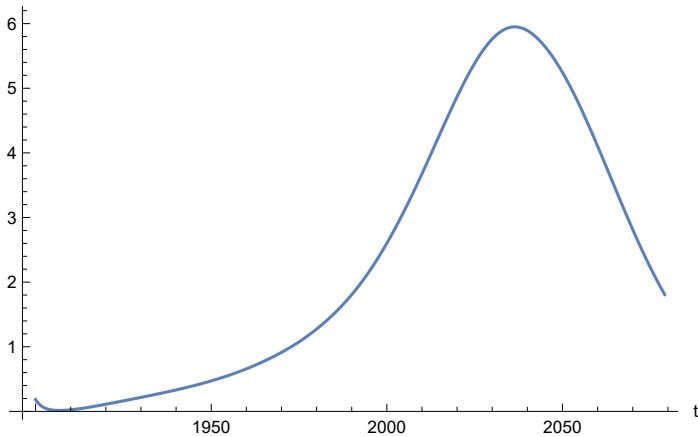
```
Maximum is 529.249
```

```
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

```
Out[81]=
```



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

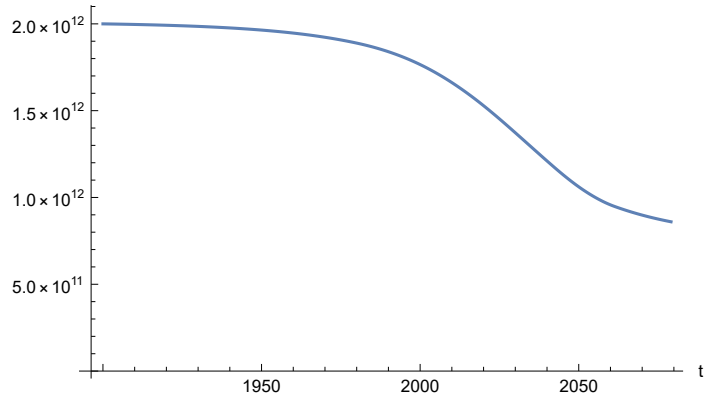
```
Maximum is 5.95005
```

```
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

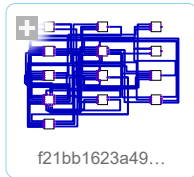
Out[83]=



APPENDIX 46. Baseline Scenario 4, Experiment 46. LE = LE/1.01, t_policy_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

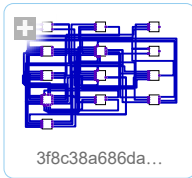
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

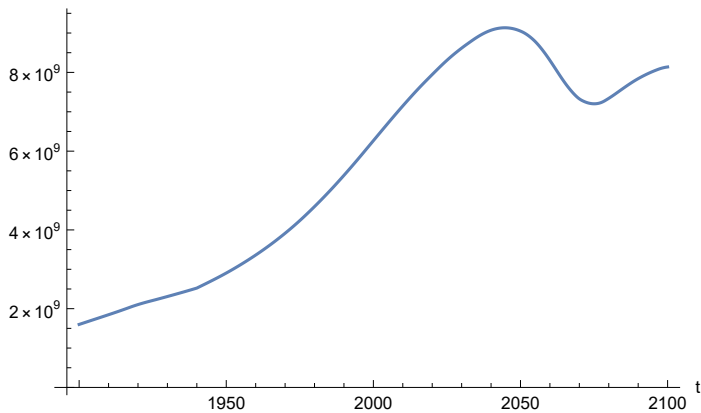
```
Out[93]=
```

```
SystemModelSimulationData [ Model: W3f8c38a686da47e1946e2bdf29dfcfaa
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[94]=
```



Find max and min of population values.

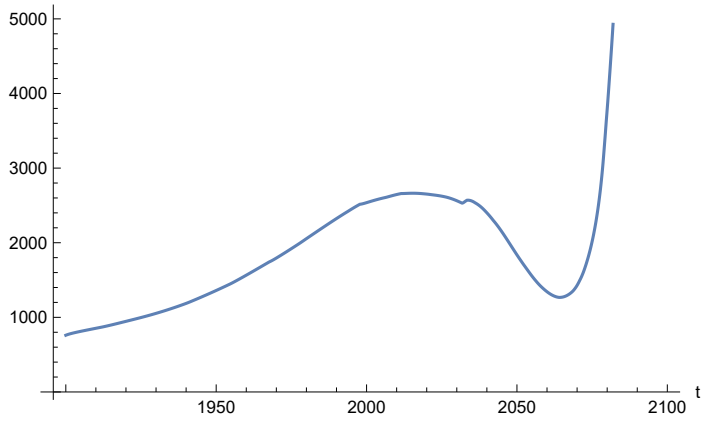
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.13317 × 109
```

```
Minimum is 1.6 × 109
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

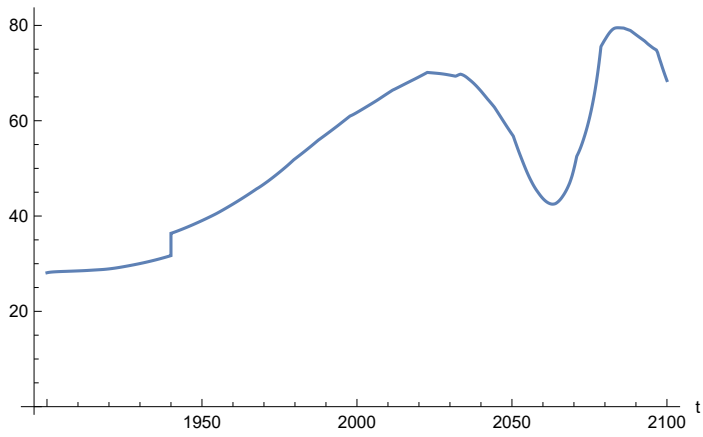
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

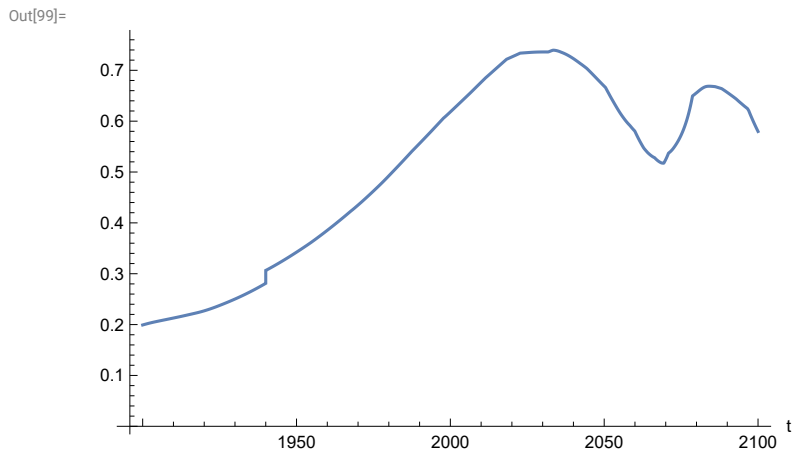
Out[97]=



In[98]:=

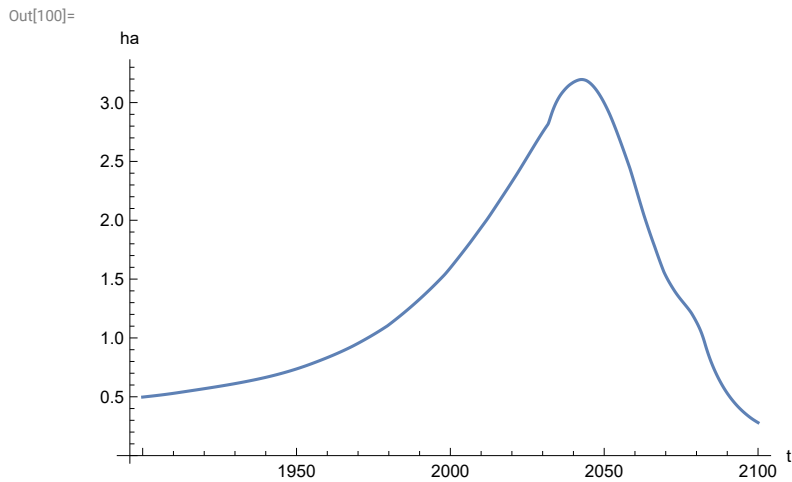
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

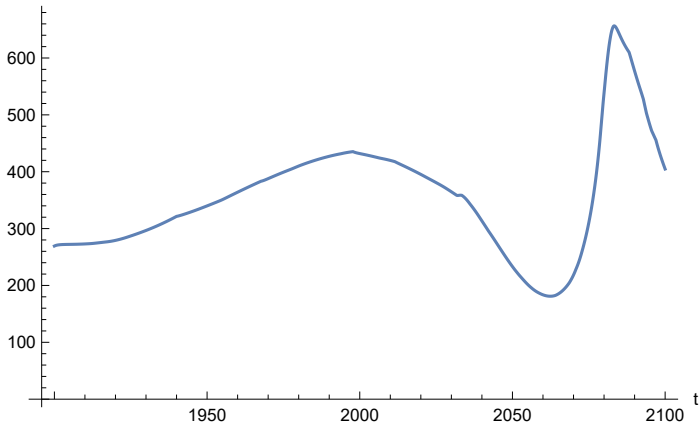


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

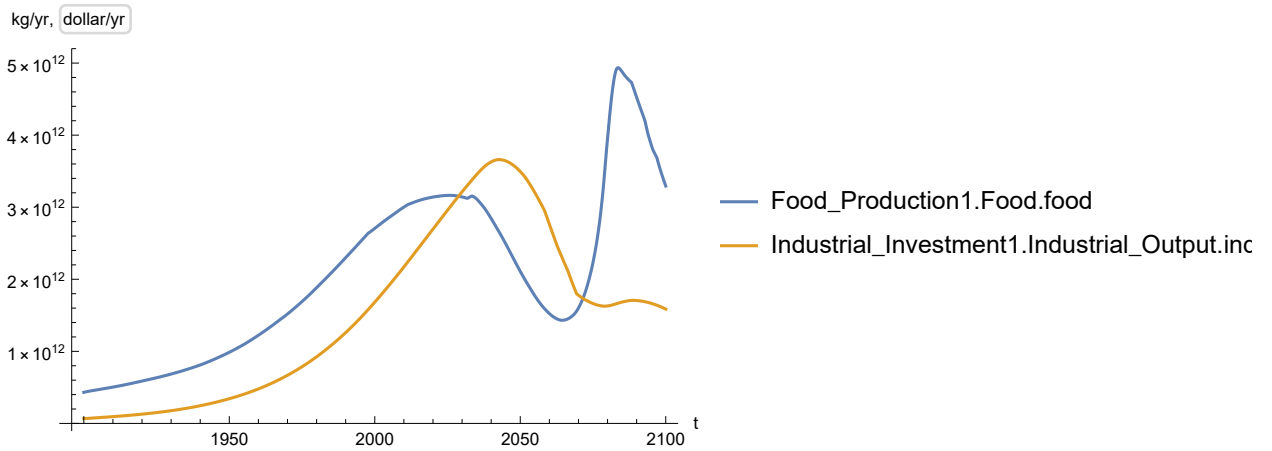


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

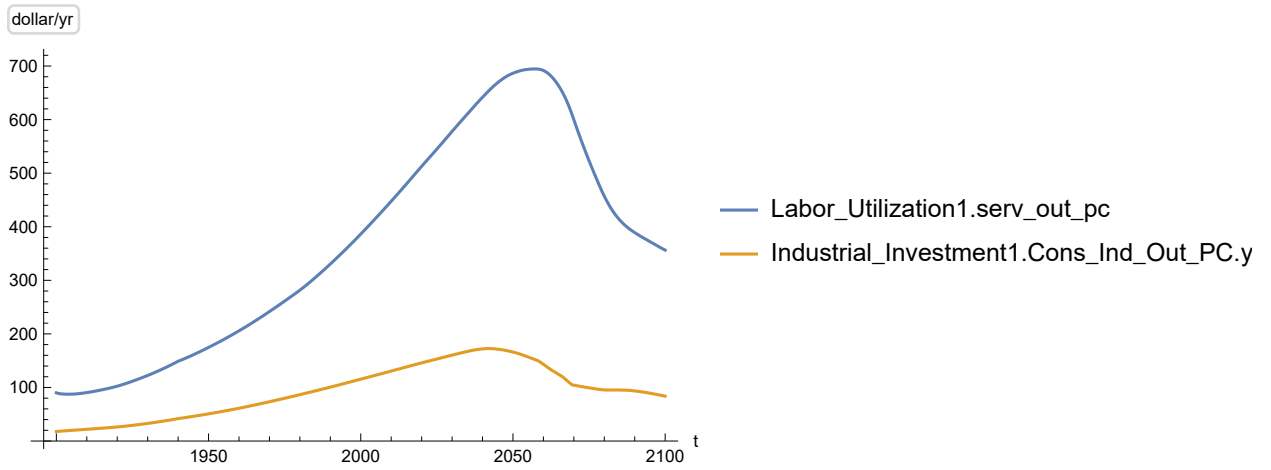


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 694.555

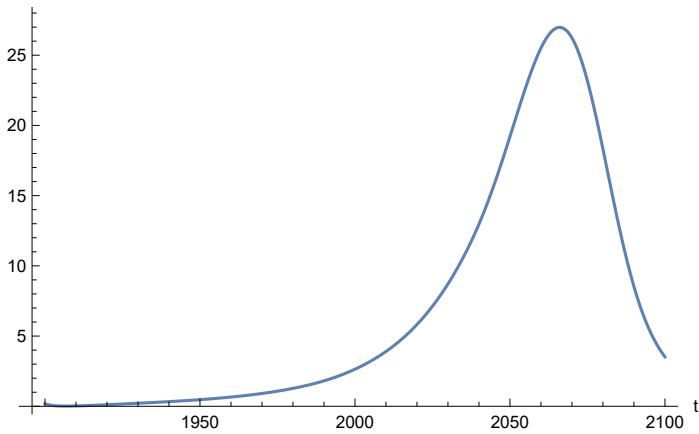
Minimum is 87.4451

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 26.9807

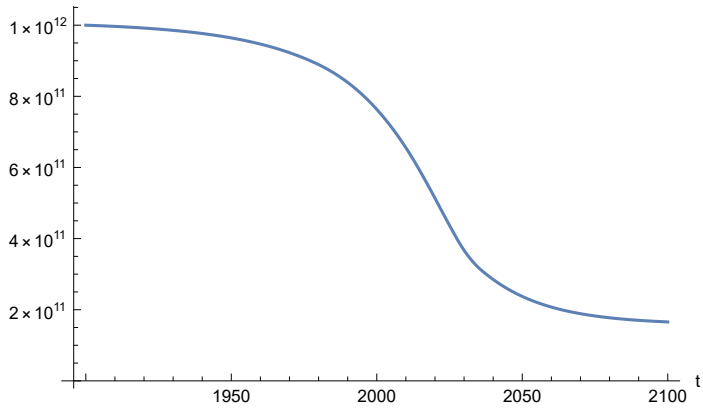
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 47. BENCHMARK SCENARIO 4, Experiment 47. $LE = LE/1.03$, $t_policy_year = 1970$.
Last modified: 28 July 2022/1530 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

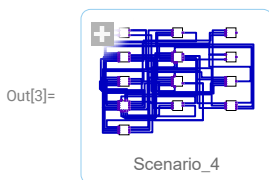
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

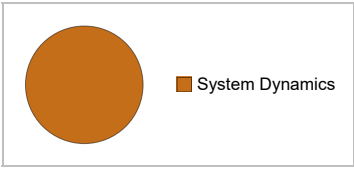
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 4.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_4"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_4
	Description	More accessible non-recoverable natural resources, pollution control, and land yield enhancement
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

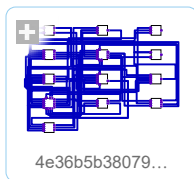
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

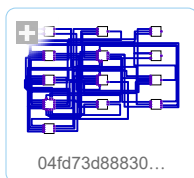
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

SystemModelSimulate: At time 2080.7 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

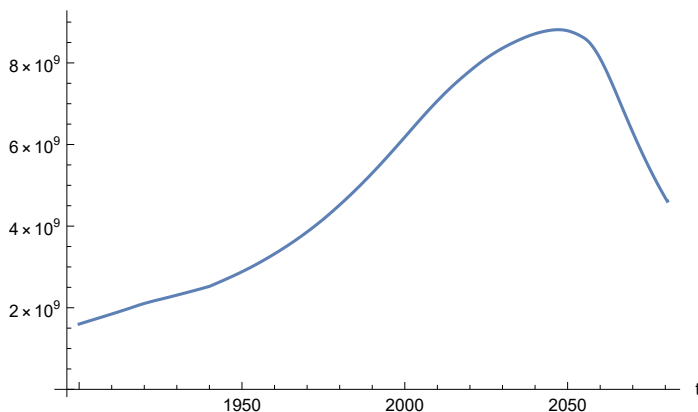
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W04fd73d88830499cbef61fac0eb67ca3  
Time:  $1.90 \times 10^3$  to  $2.08 \times 10^3$  ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[22]=
```



Find max and min of population values.

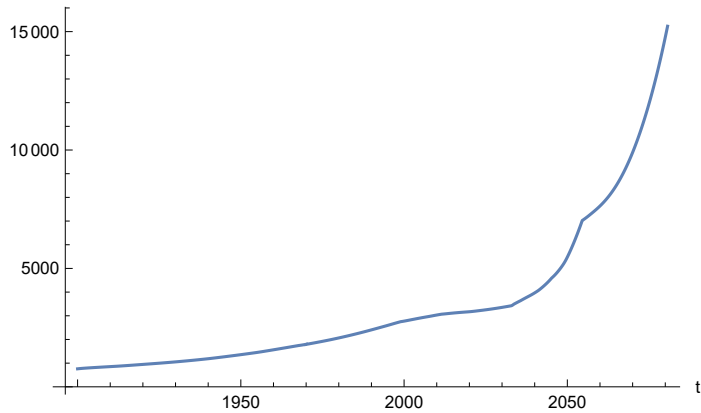
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.81411×10^9

Minimum is 1.6×10^9

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

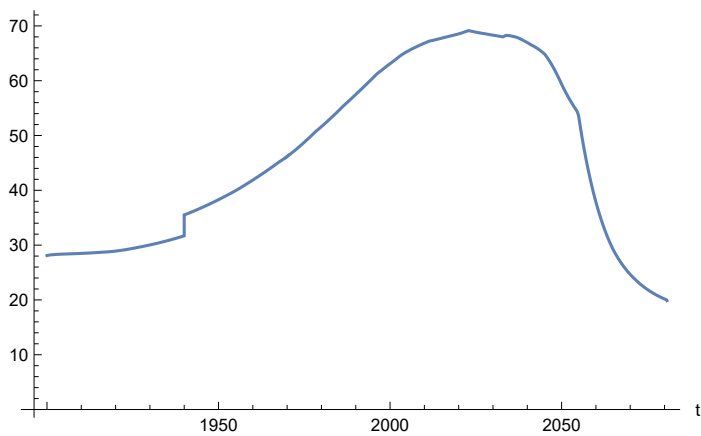
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[25]=

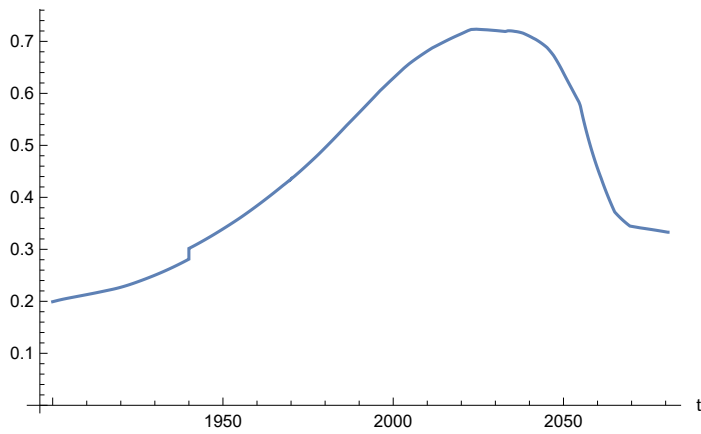


In[26]=

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

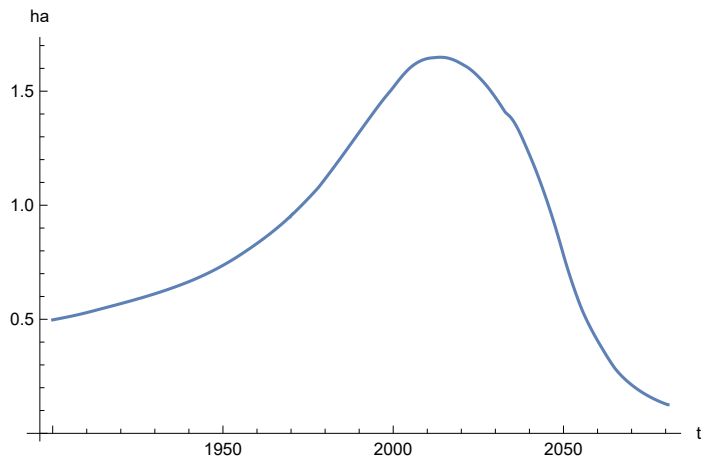
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```

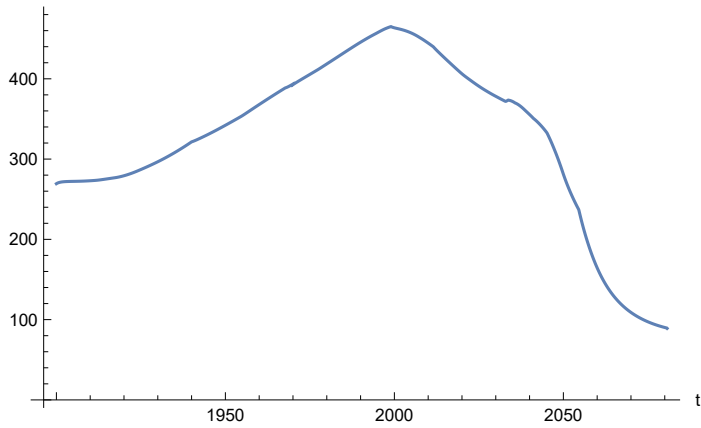
Out[28]=



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

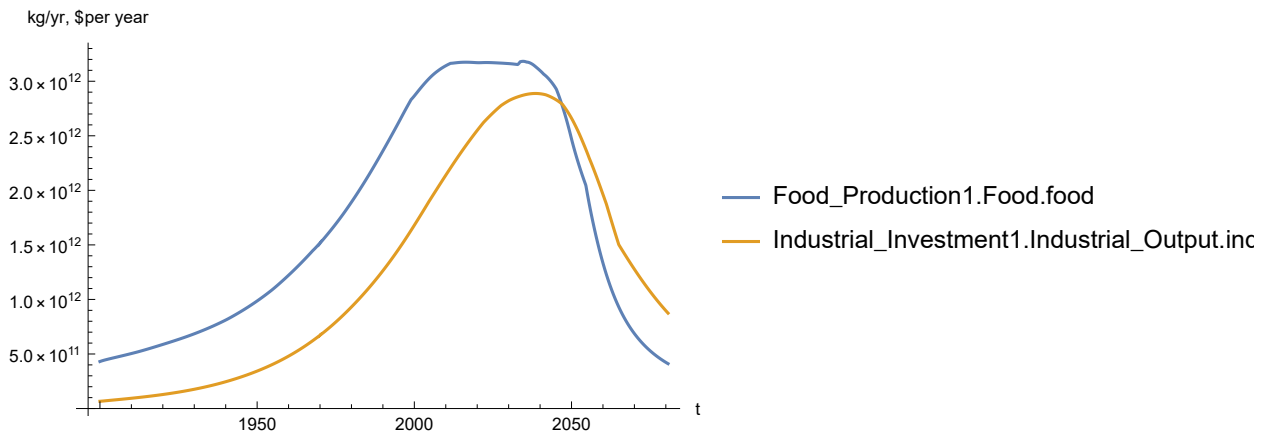
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

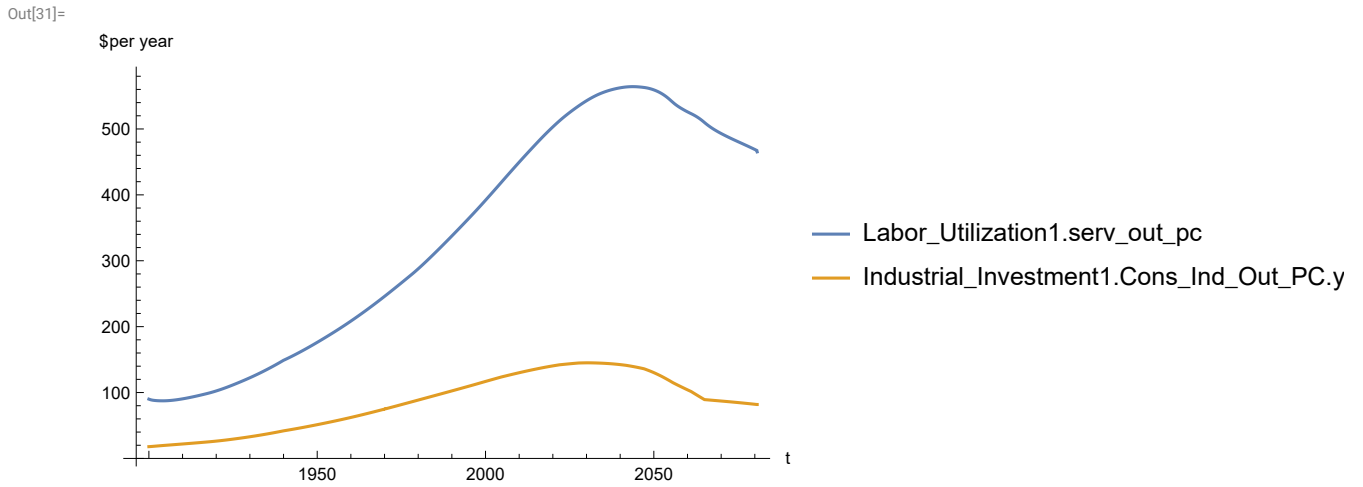
In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

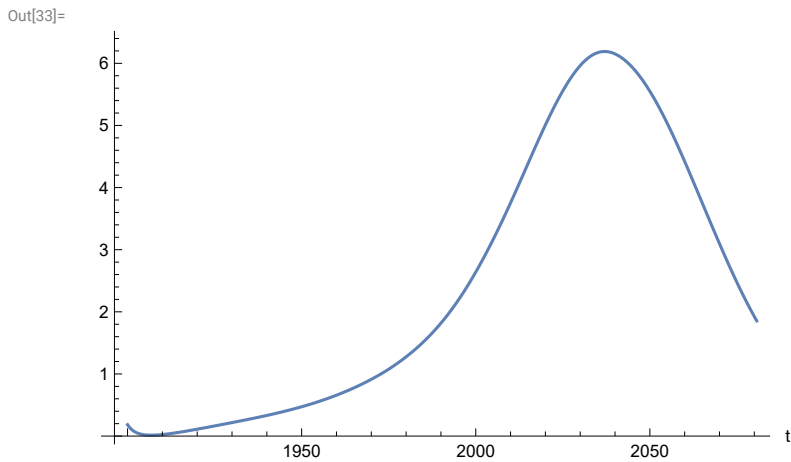


Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 564.223
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



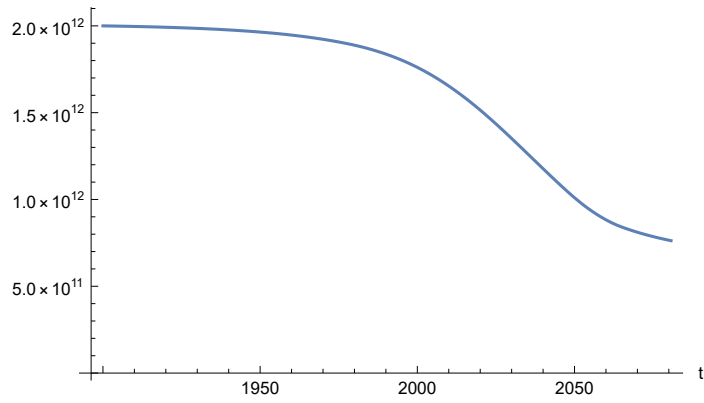
Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 6.19007
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

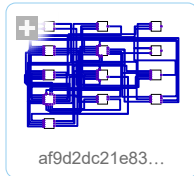


APPENDIX 48. LE/1.03, t_policy_year = 2025. Baseline Scenario 4, Experiment 48.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

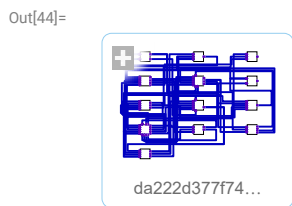
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```



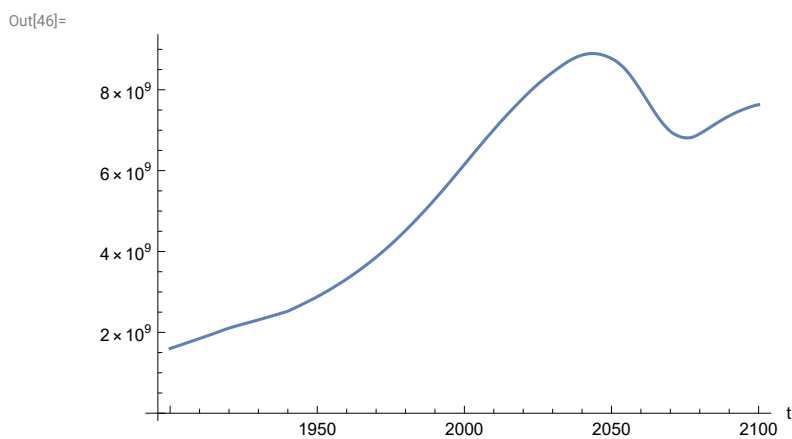
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

```
Out[45]= SystemModelSimulationData [
  Model: Wda222d377f744247978aeee03a3136ed
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

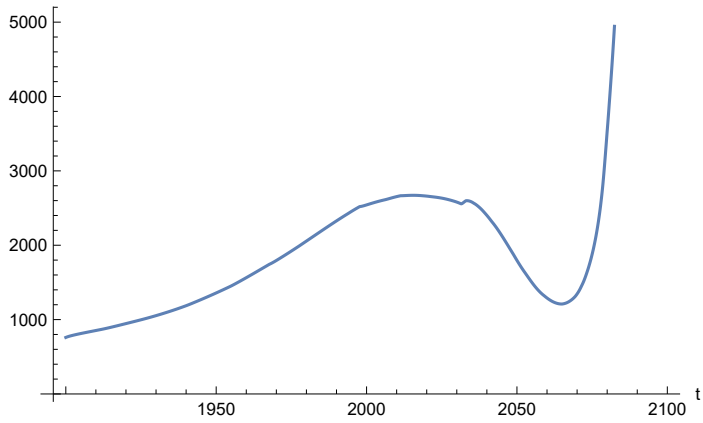
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.89631 × 109
```

```
Minimum is 1.6 × 109
```

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

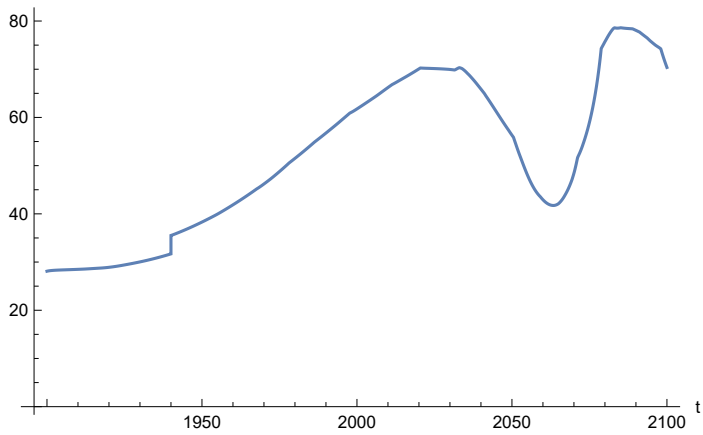
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

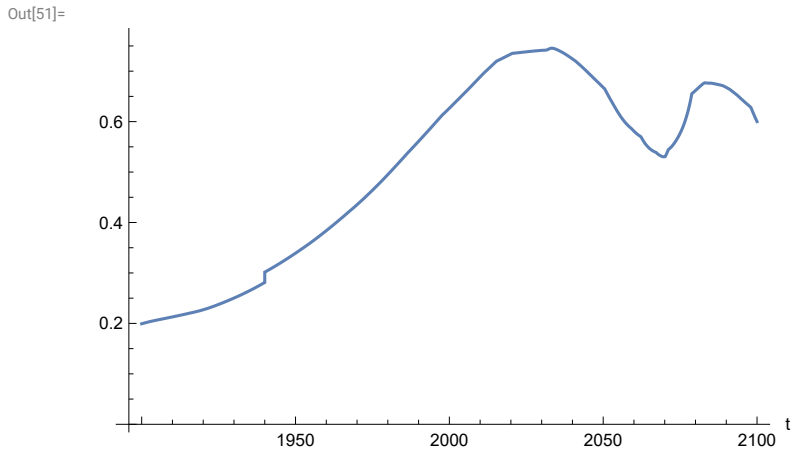
Out[49]=



In[50]:=

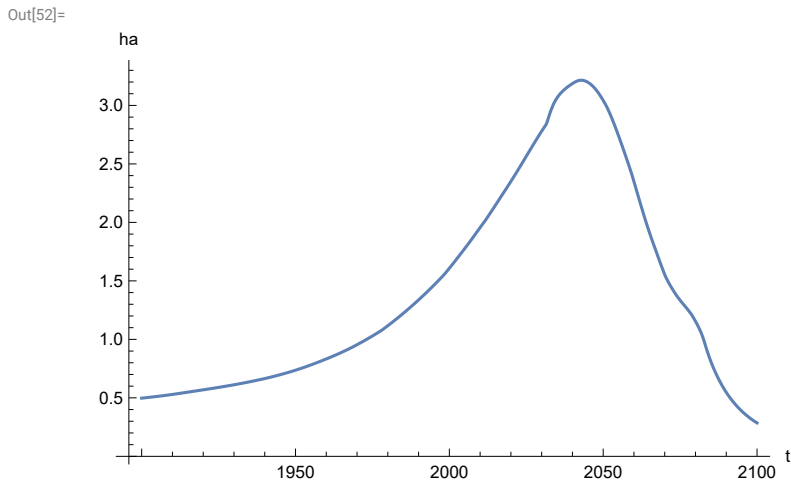
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

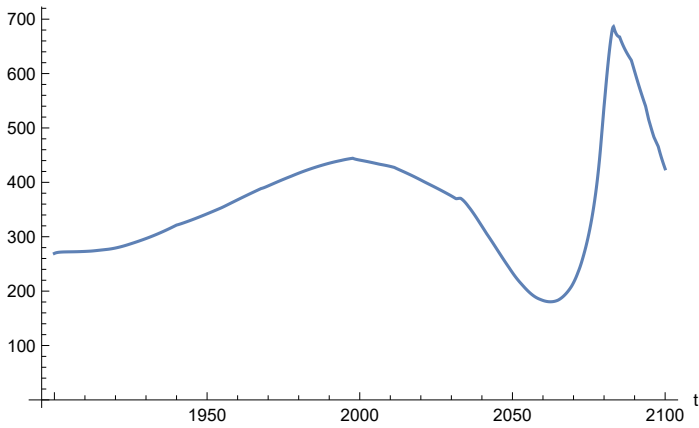
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

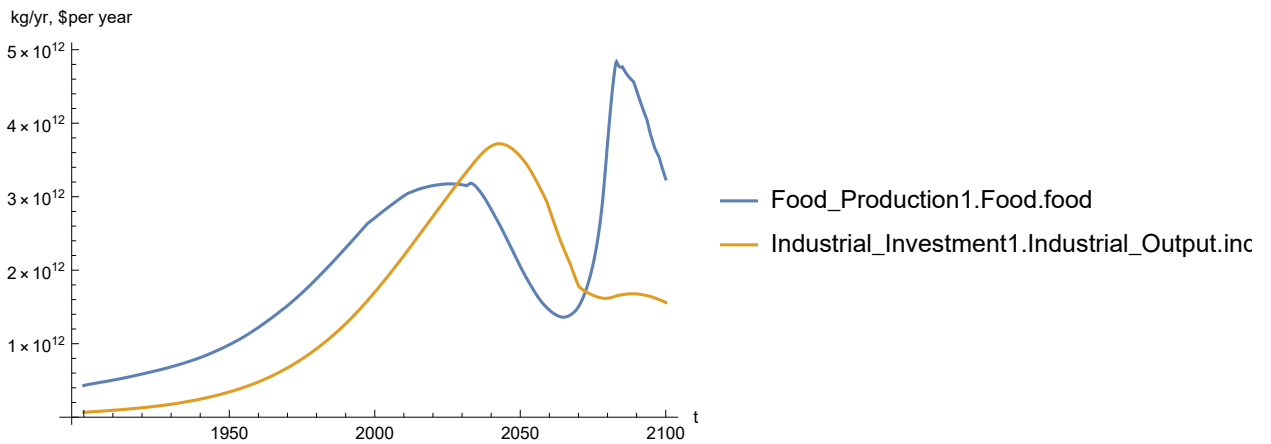
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

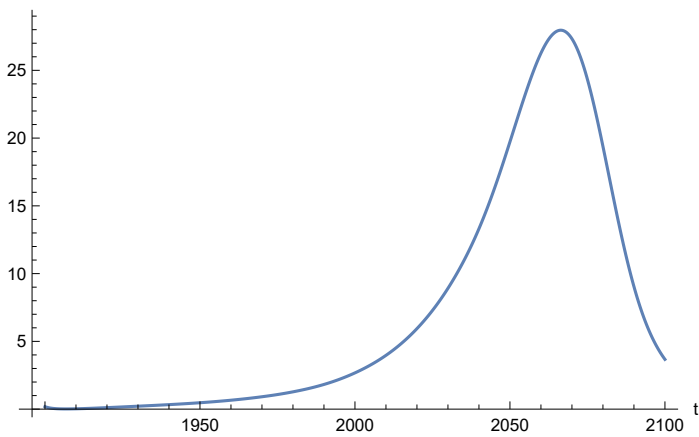


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 734.546
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



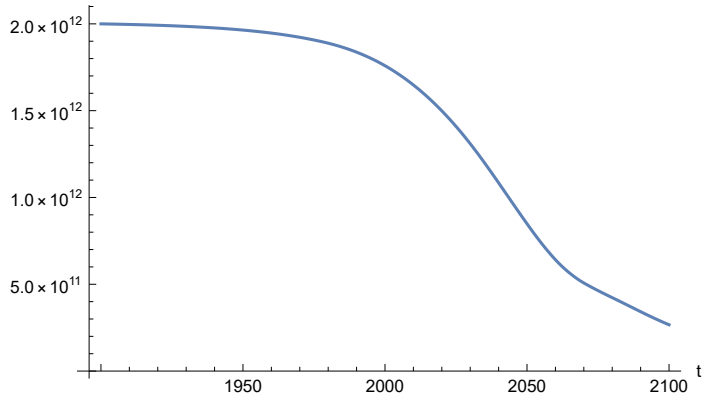
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 27.96
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

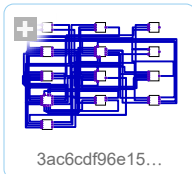


APPENDIX 49. LE/1.05, t_policy_year = 1970. Baseline Scenario 4, Experiment 49.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

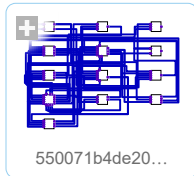
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set t_policy_year to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

```
SystemModelSimulate: At time 2081.2 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range
```

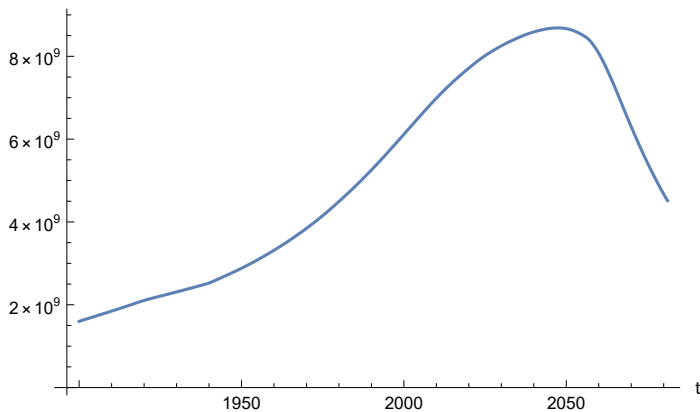
```
Out[69]=
```

```
SystemModelSimulationData [
  Model: W550071b4de20452c9fffd5d88f81f581
  Time: 1.90 × 103 to 2.08 × 103 ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



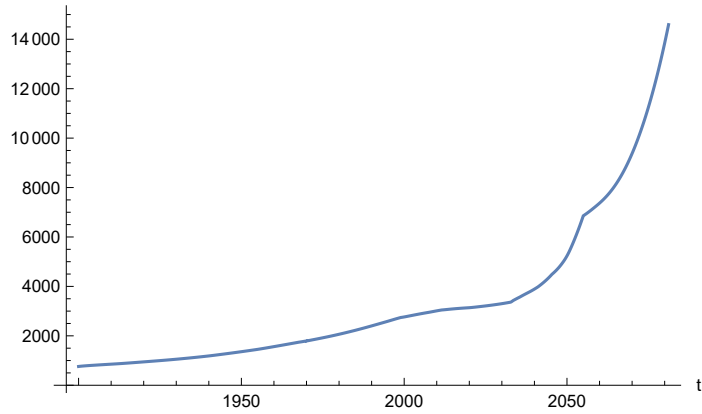
Find max and min of population values.

```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.68586×10^9

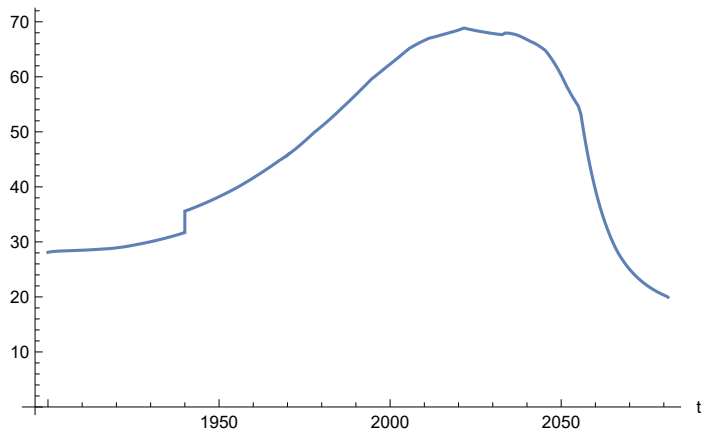
Minimum is 1.6×10^9

```
In[72]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[72]=
```



Plot life expectancy, years.

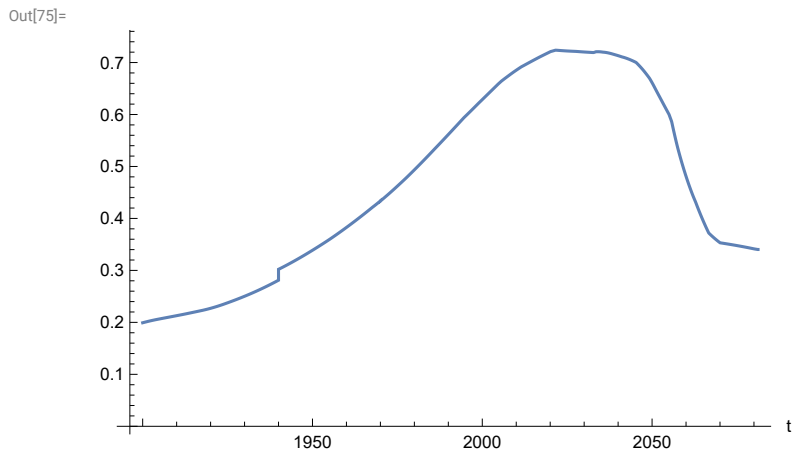
```
In[73]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[73]=
```



```
In[74]:=
```

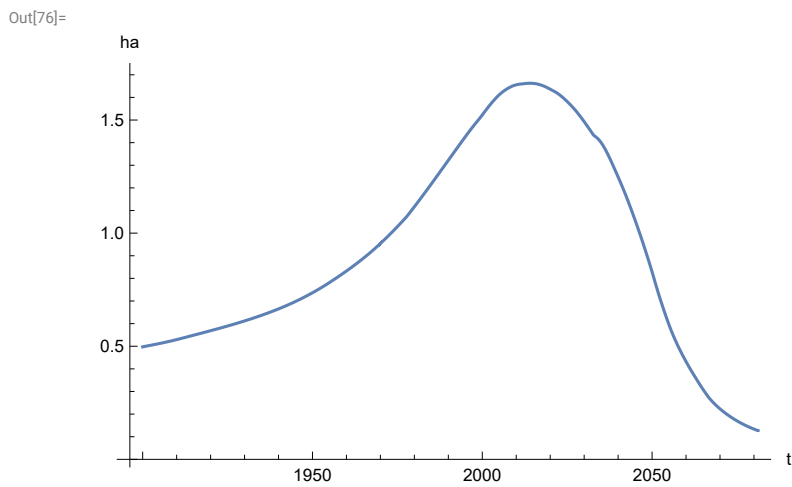
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,  
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



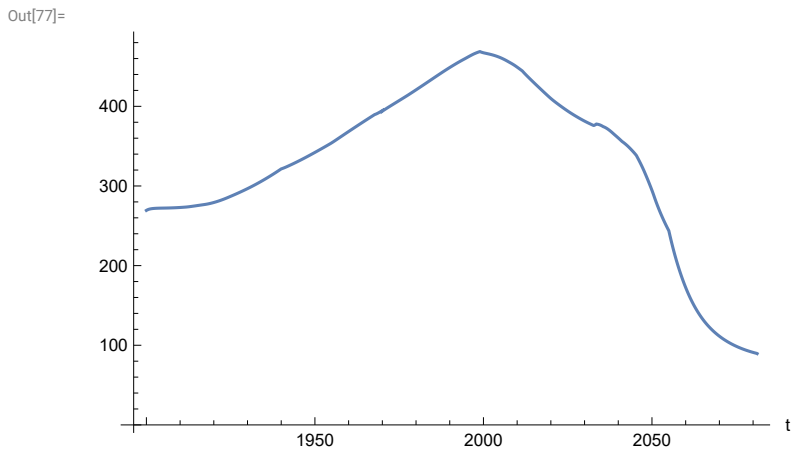
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,  
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
  _footprint"}]
```



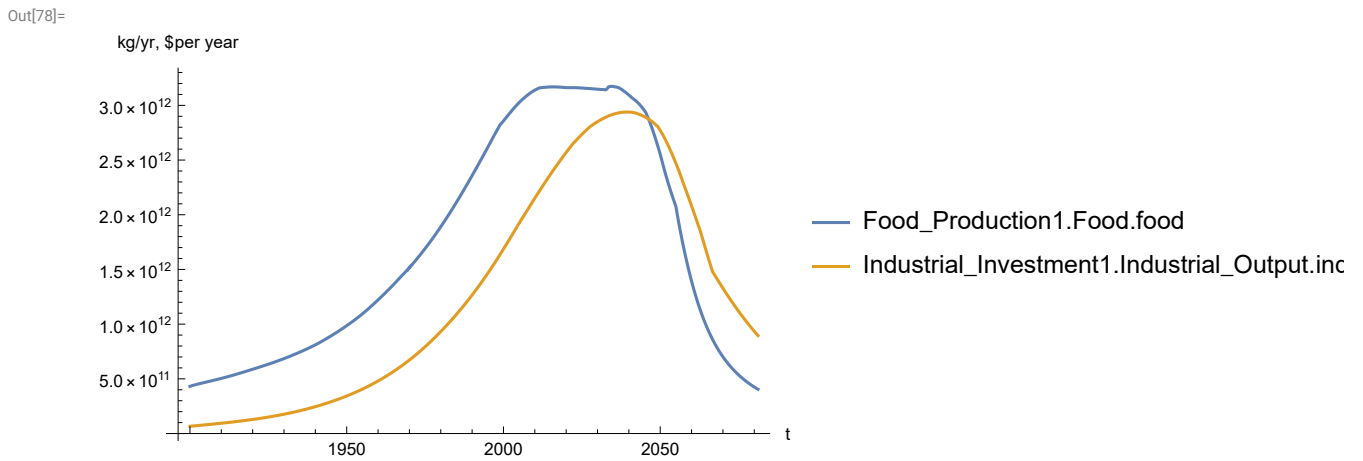
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

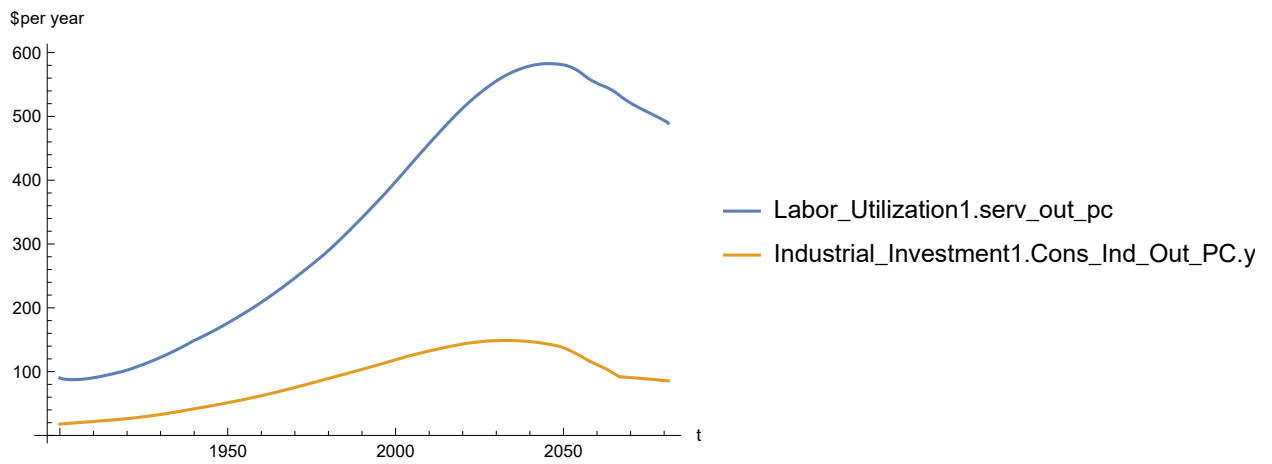
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



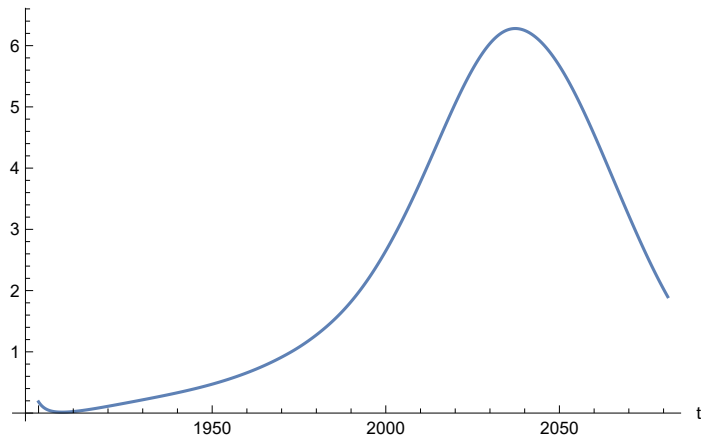
Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 582.708
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



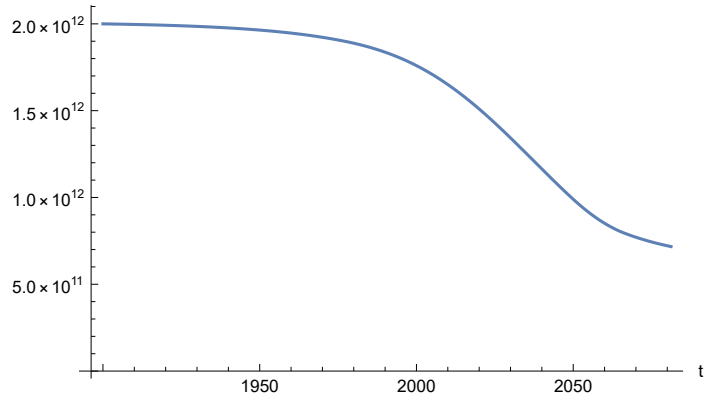
Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 6.27961
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

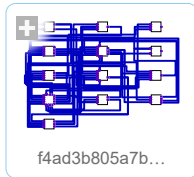
Out[83]=



APPENDIX 50. Baseline Scenario 4, Experiment 50. LE = LE/1.05, t_policy_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

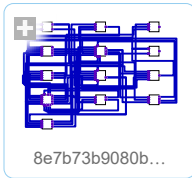
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



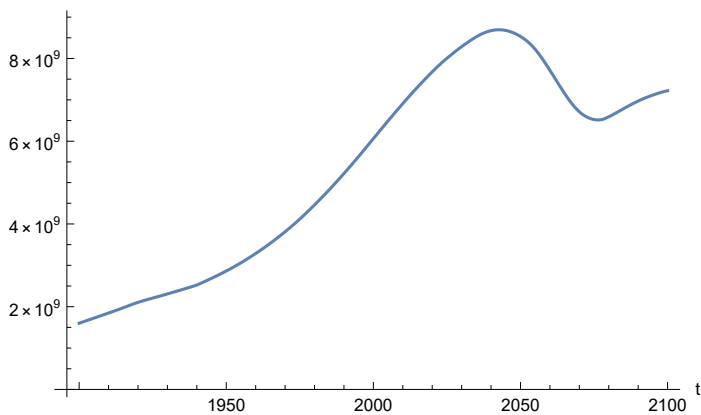
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

SystemModelSimulationData [ Model: W8e7b73b9080b4f4dae88065dc82f5462
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

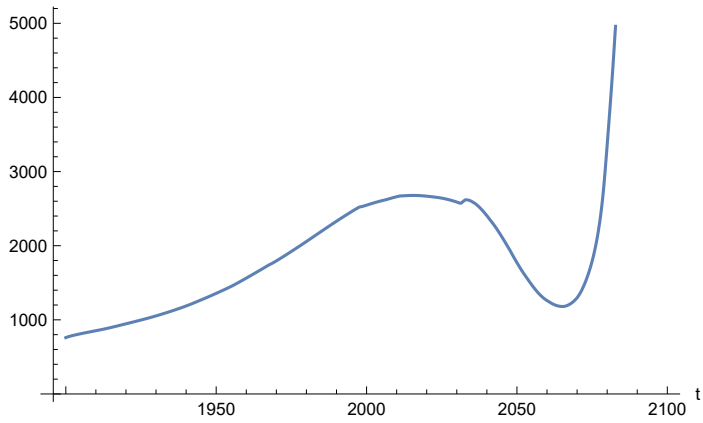


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.69407 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

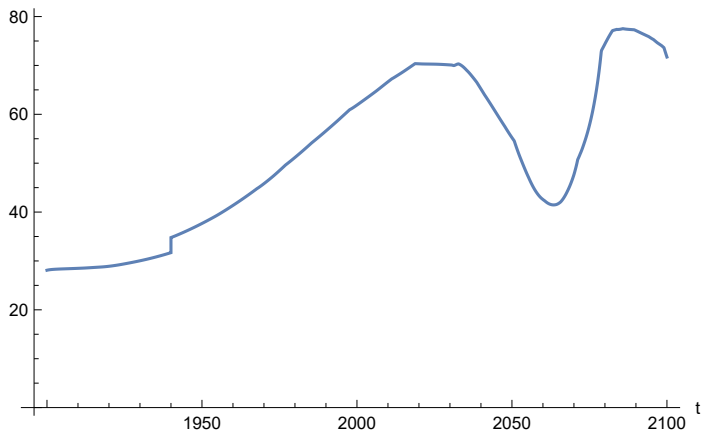
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

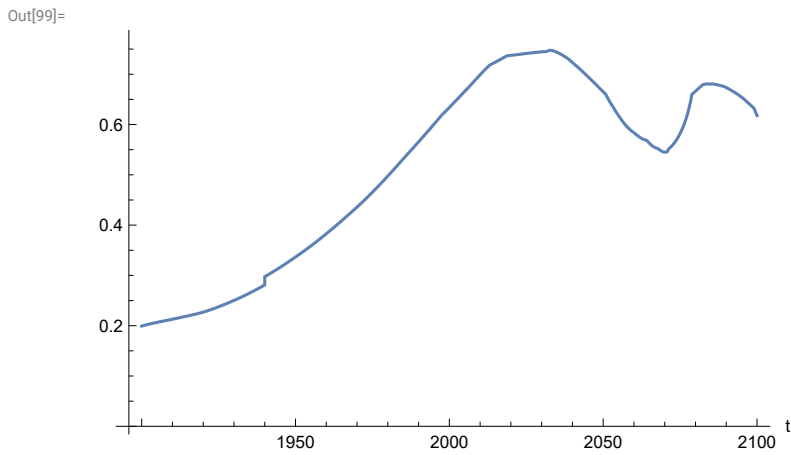
Out[97]=



```
In[98]:=
```

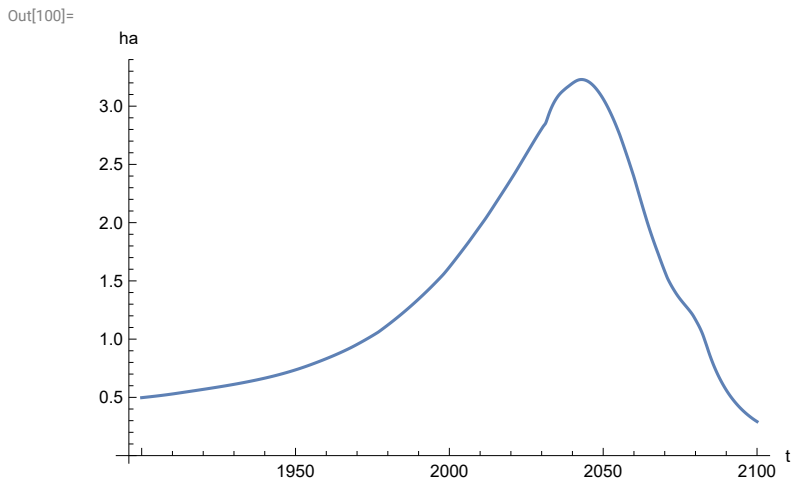
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

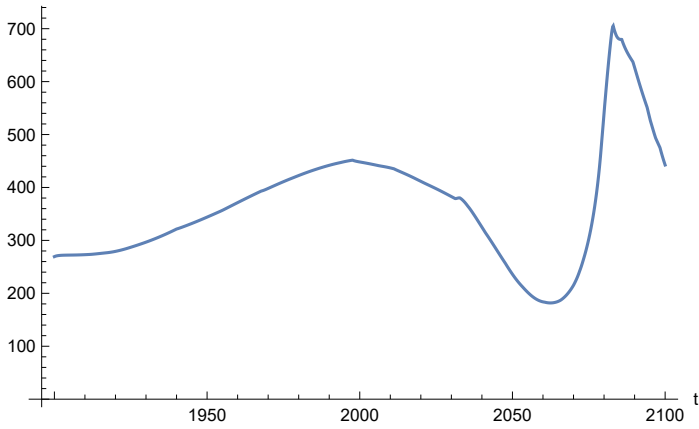


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

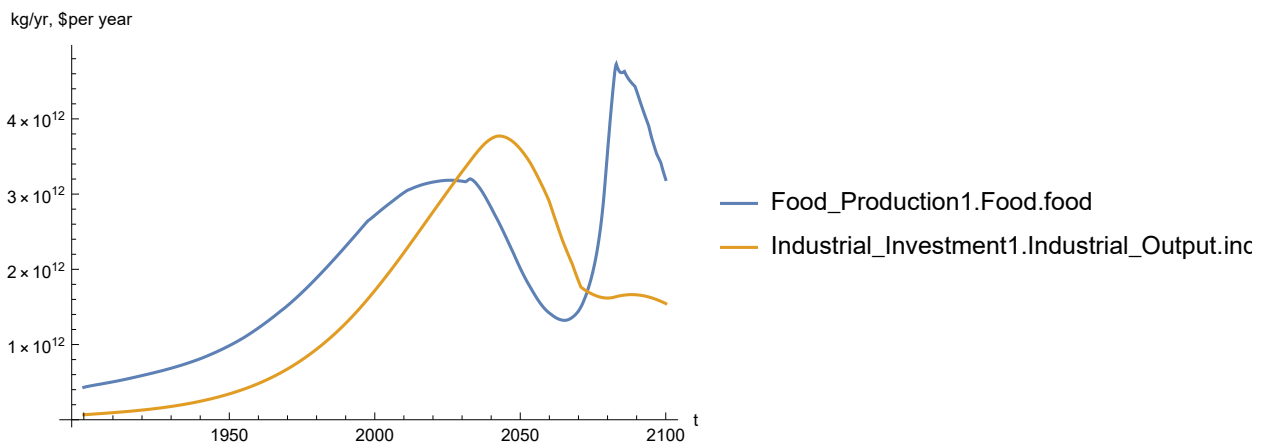


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

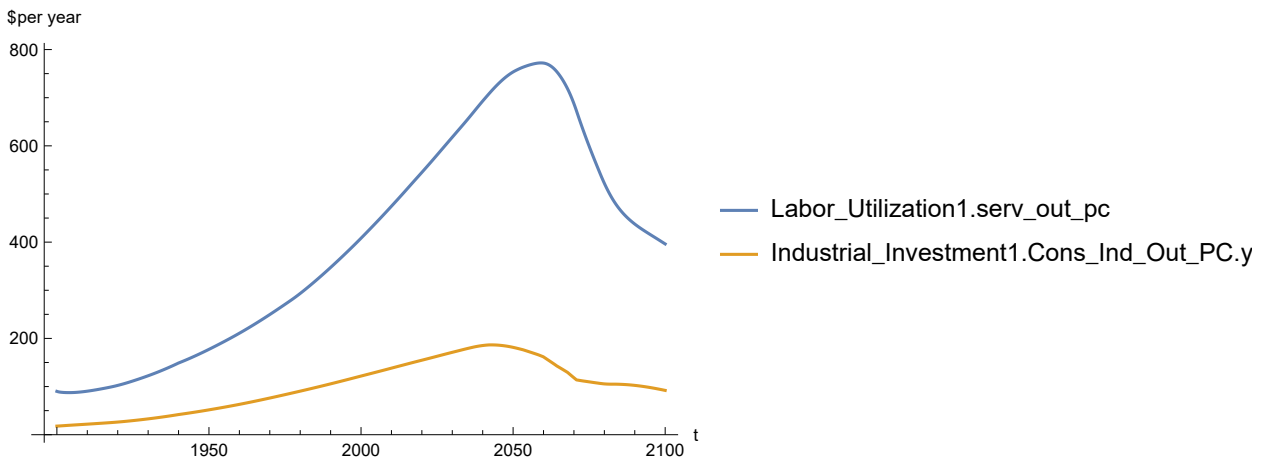


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

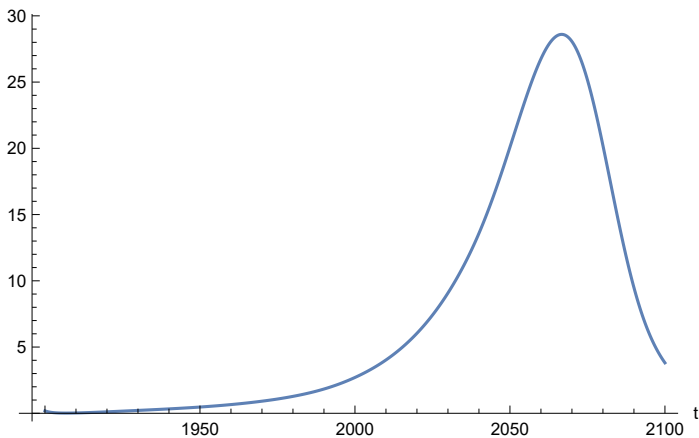
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 772.235
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 28.601

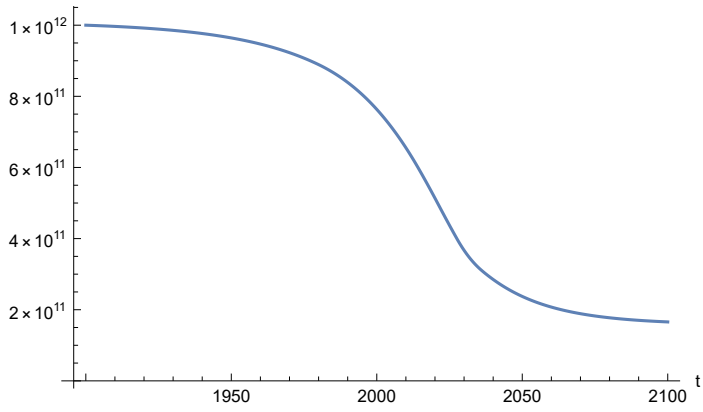
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 51. BENCHMARK SCENARIO 4, Experiment 51. $LE = LE/1.1$, $t_policy_year = 1970$.
Last modified: 28 July 2022/1700 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

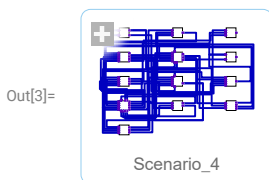
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

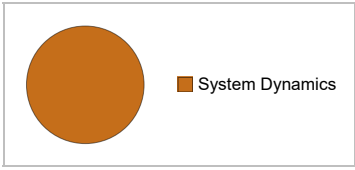
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 4.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_4"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	M	SystemDynamics.WorldDynamics.World3.Scenario_4
	D	More accessible non-recoverable natural resources, pollution control, and land yield enhancement
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

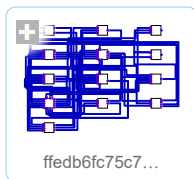
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

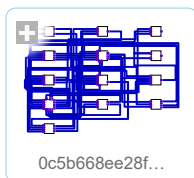
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

SystemModelSimulate: At time 2086. s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

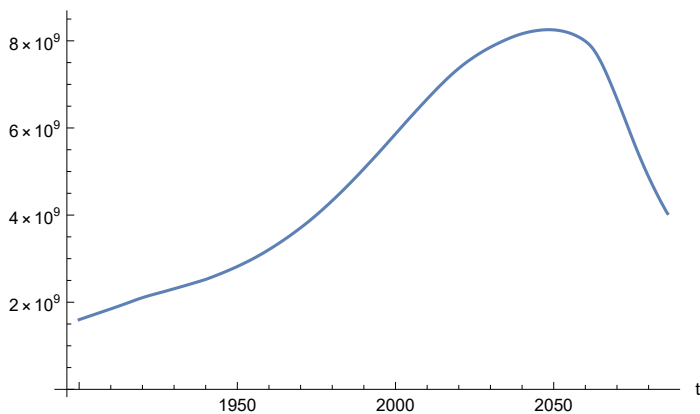
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W0c5b668ee28f482bbac8ea1221a487de  
Time: 1.90 × 103 to 2090. ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

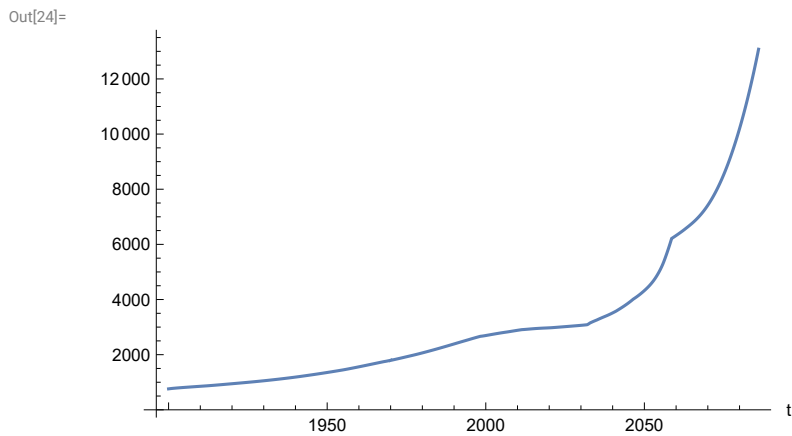
```
Out[22]=
```



Find max and min of population values.

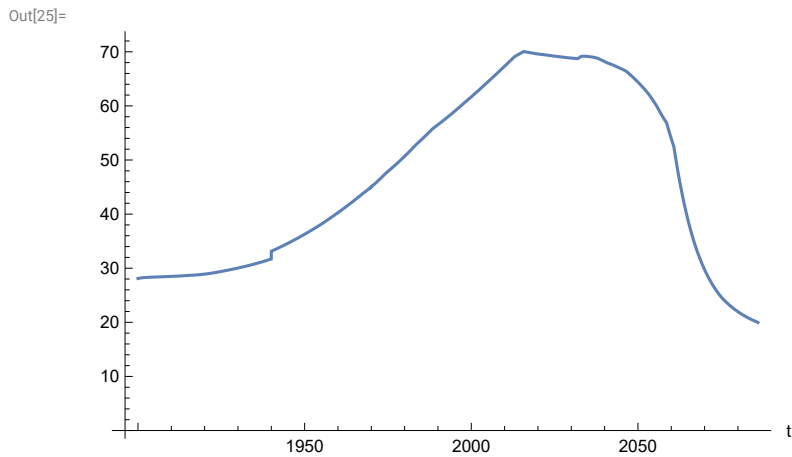
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.25583 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

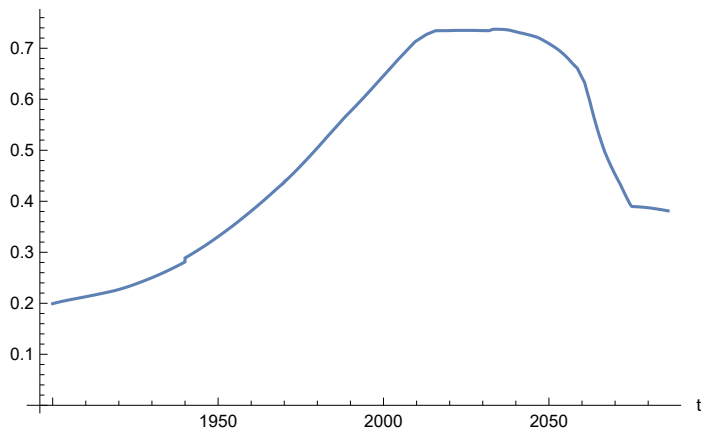


```
In[26]:=
```

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,  
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

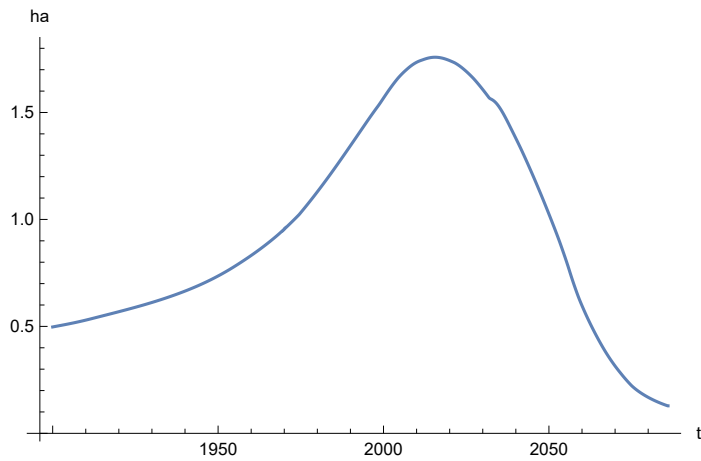
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,  
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
 _footprint"}]
```

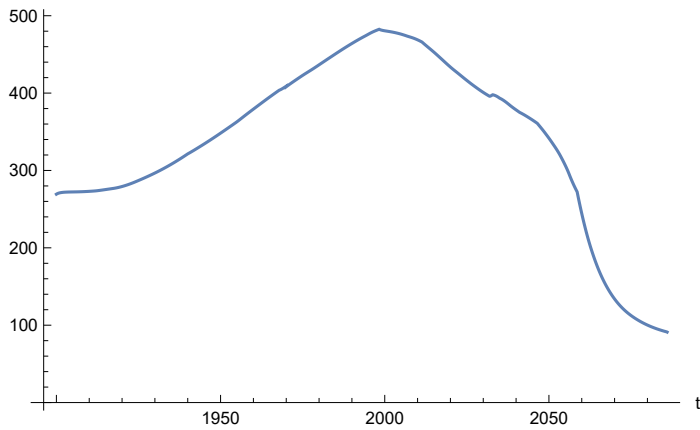
Out[28]=



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

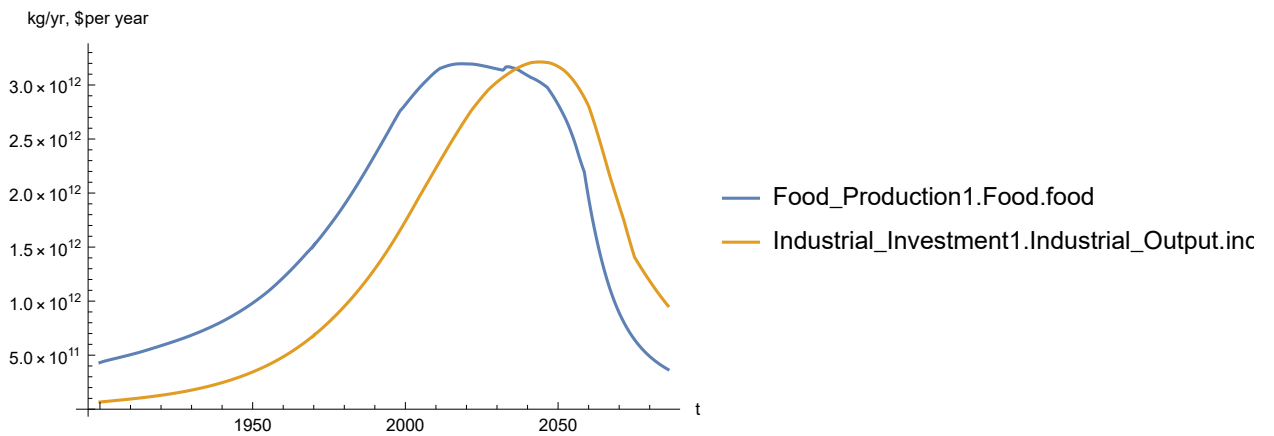
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

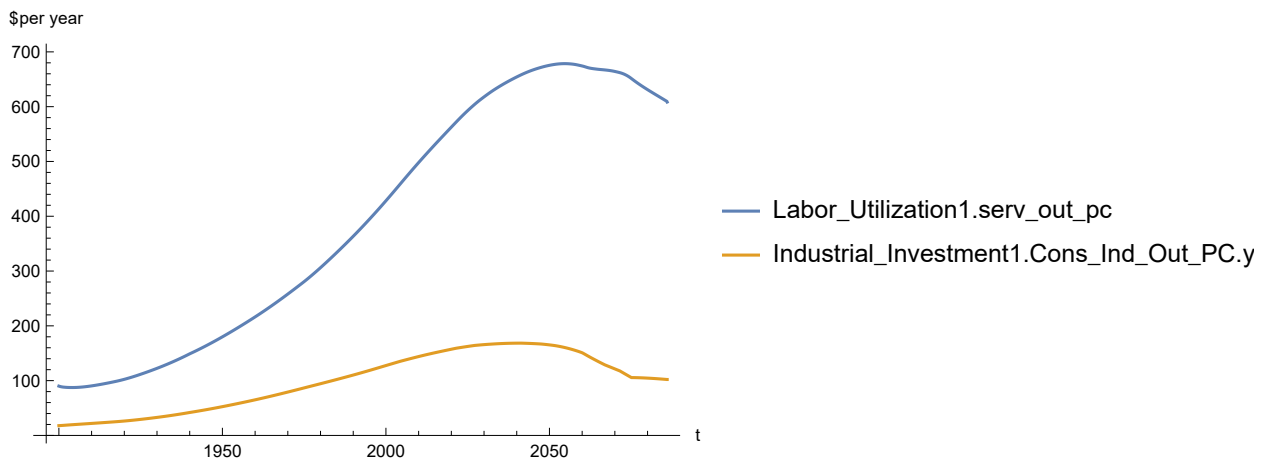
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

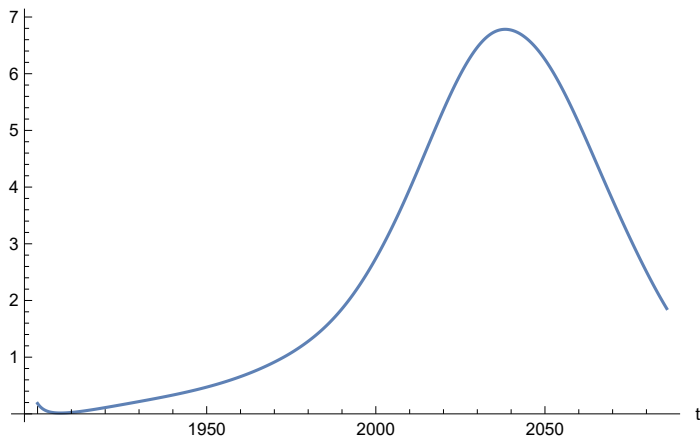
Maximum is 678.503

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

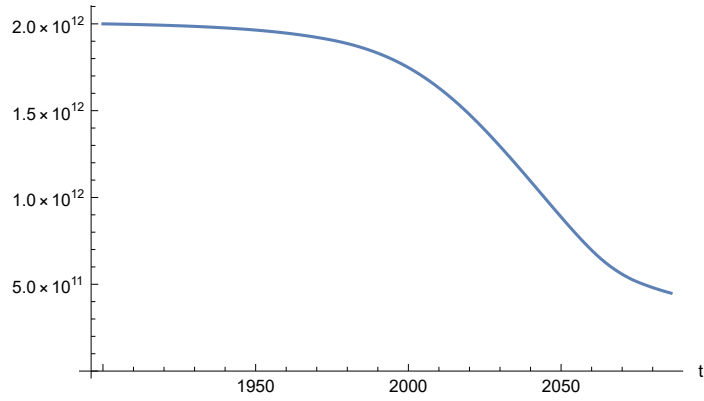
Maximum is 6.78311

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

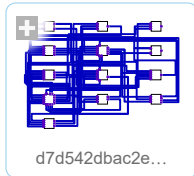


APPENDIX 52. LE/1.1, t_policy_year = 2025. Baseline Scenario 4, Experiment 52.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

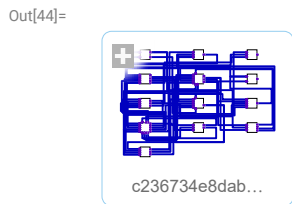
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}



Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```



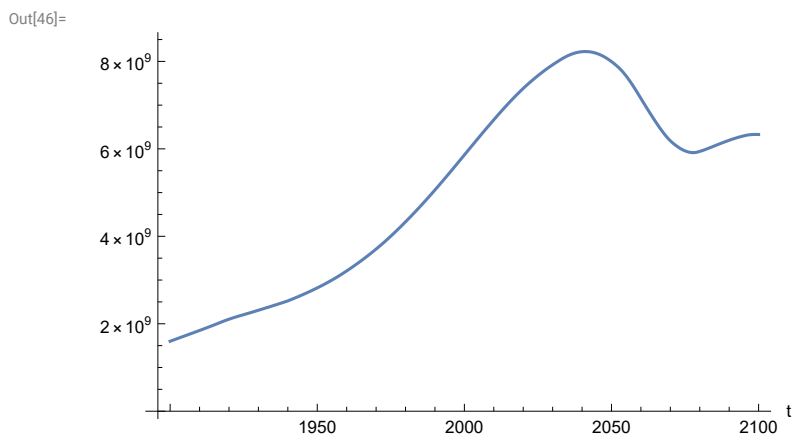
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [  Model: Wc236734e8dab49c18fed926d795a1770
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

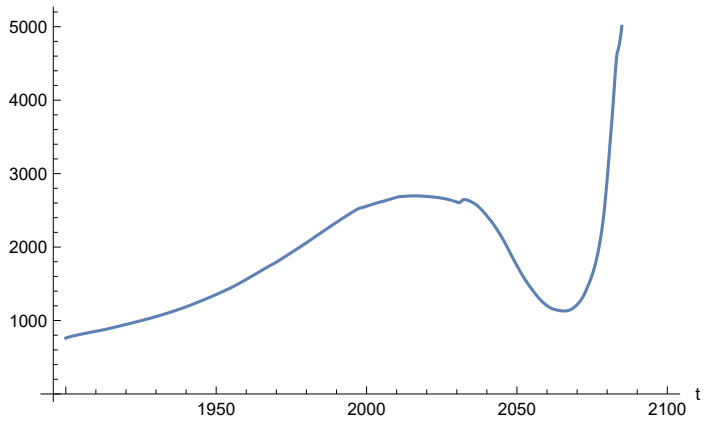
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.22547×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

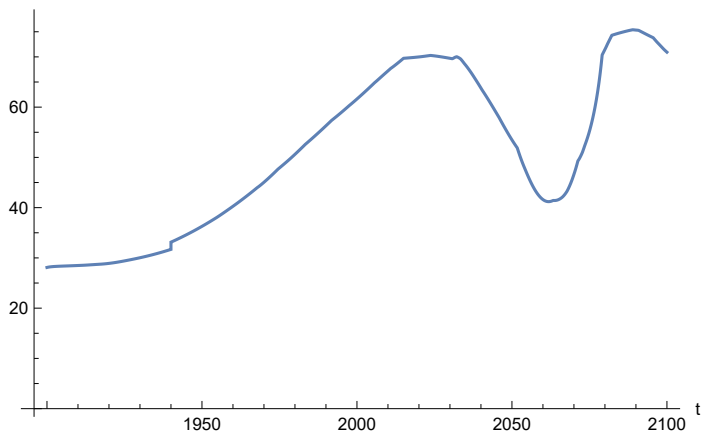
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

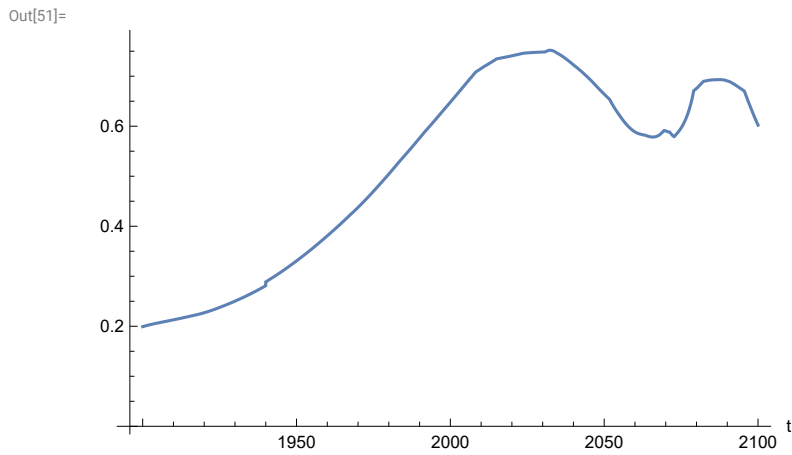
Out[49]=



In[50]:=

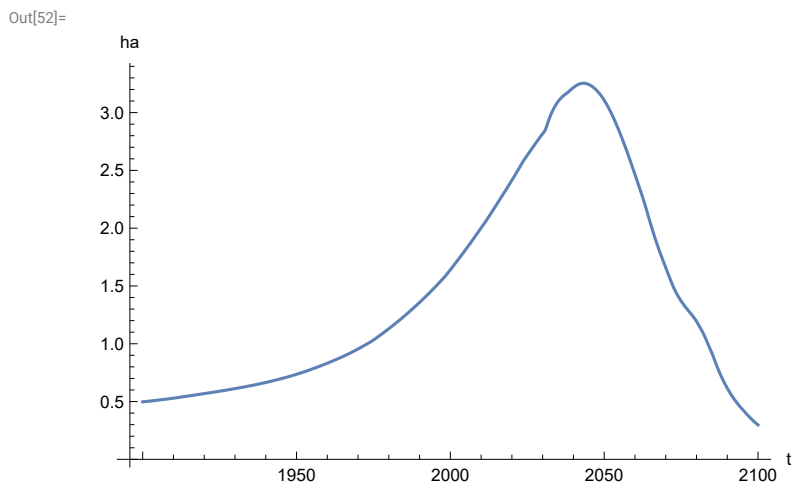
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



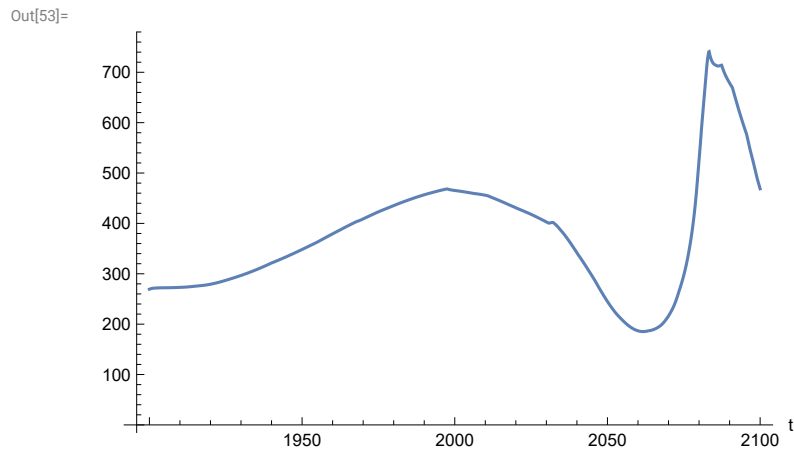
Plot per capita ecological footprint, hectares.

```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



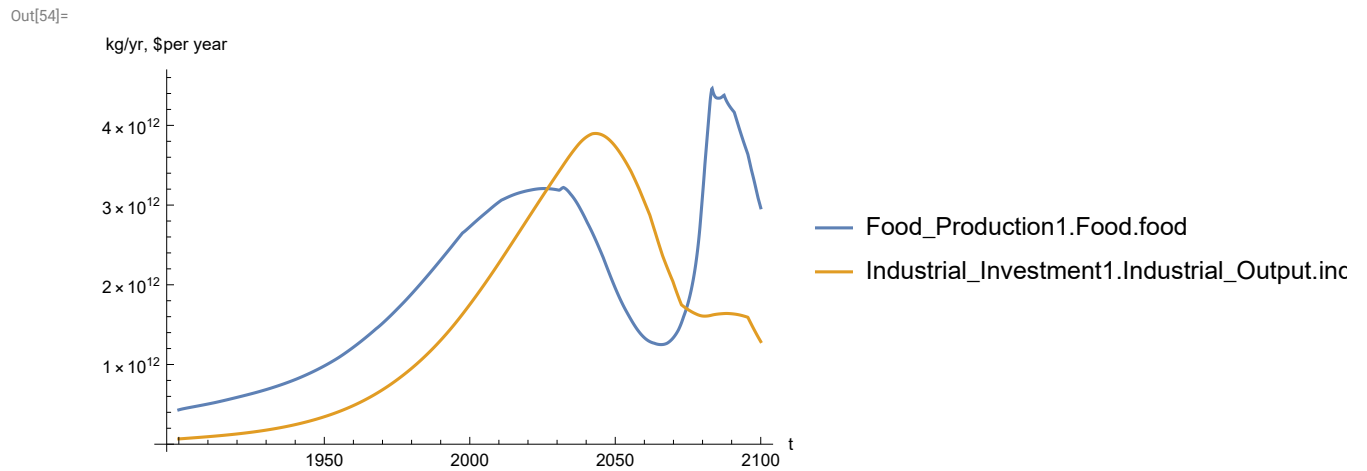
Plot food production per capita (kg/year).

```
In[53]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



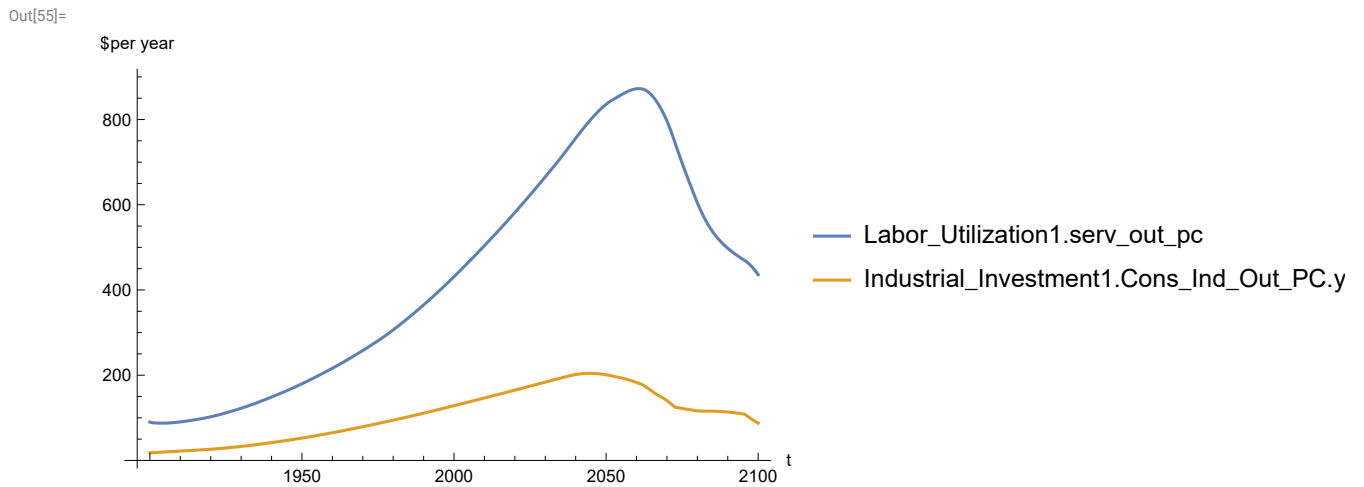
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[54]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

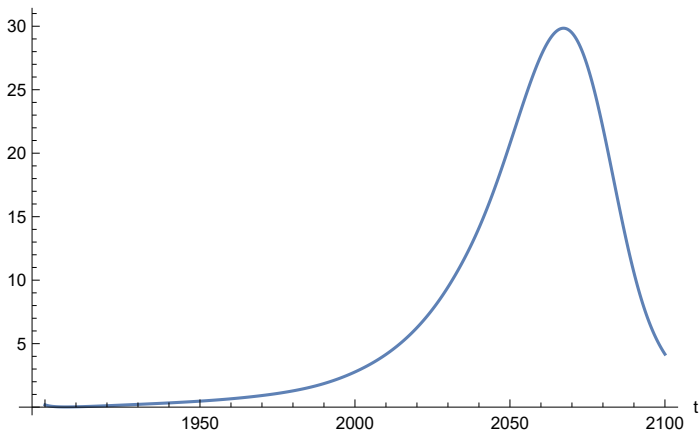


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 872.459
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



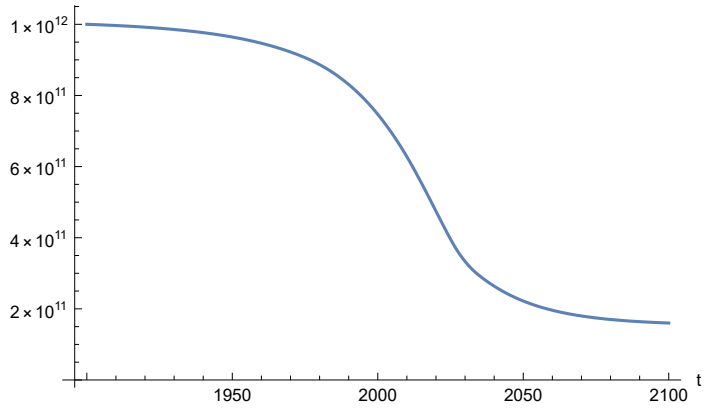
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 29.8441
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=



APPENDIX 4A1. BENCHMARK SCENARIO 8, Experiment 4A1. $LE = LE/1.001$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1255 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

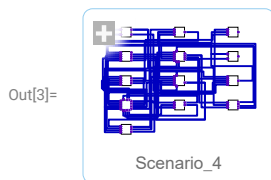
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

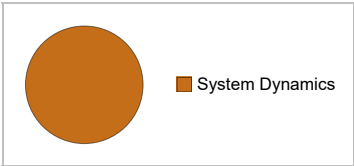
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 4.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_4"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_4
	D	More accessible non-recoverable natural resources, pollution control, and land yield enhancement
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

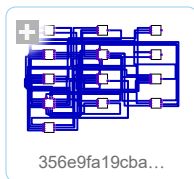
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```


```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

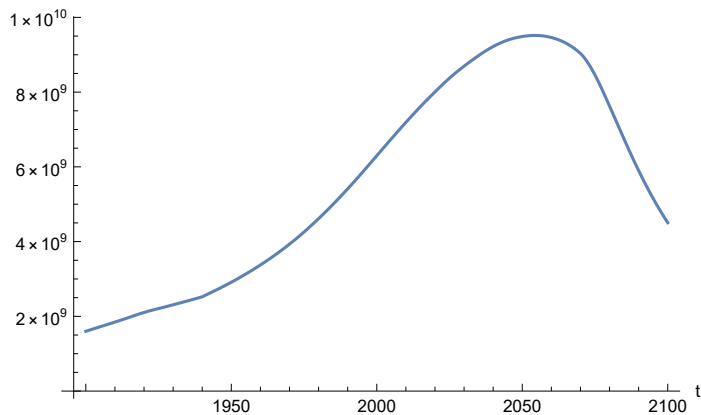
```
Out[20]=
```

```
SystemModelSimulationData [  Model: W356e9fa19cba40cdb9969da2788971da  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

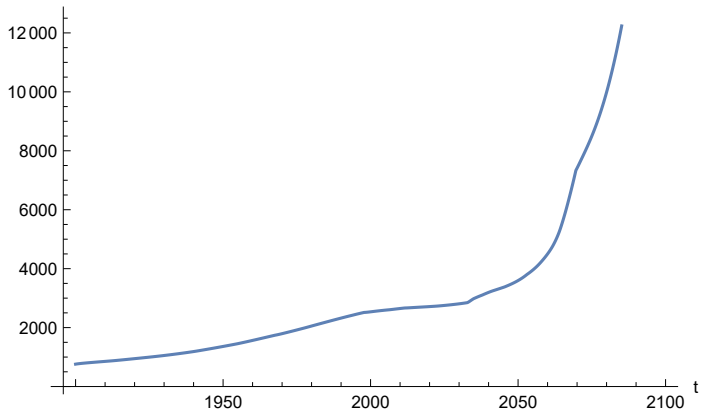
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.51746 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[23]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

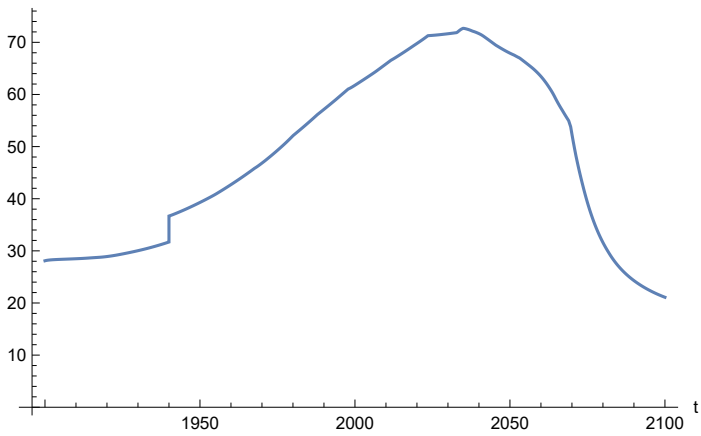
Out[23]=



Plot life expectancy, years.

```
In[24]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

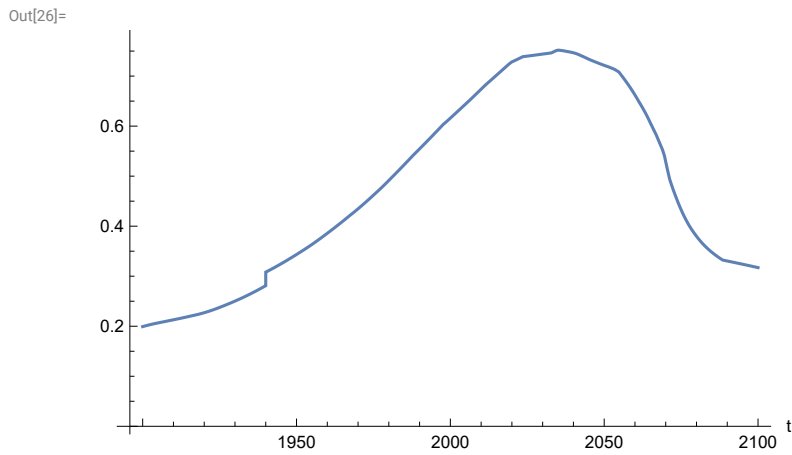
Out[24]=



In[25]=

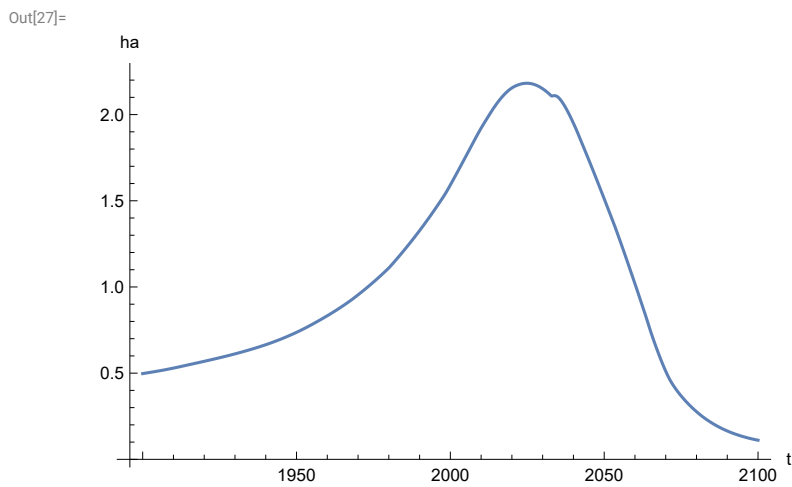
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

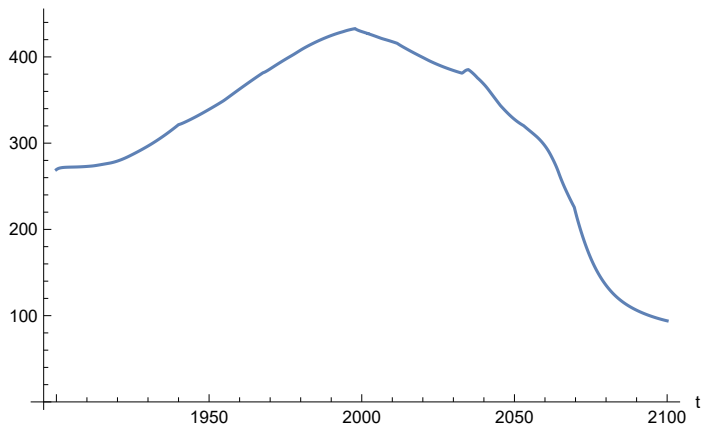
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

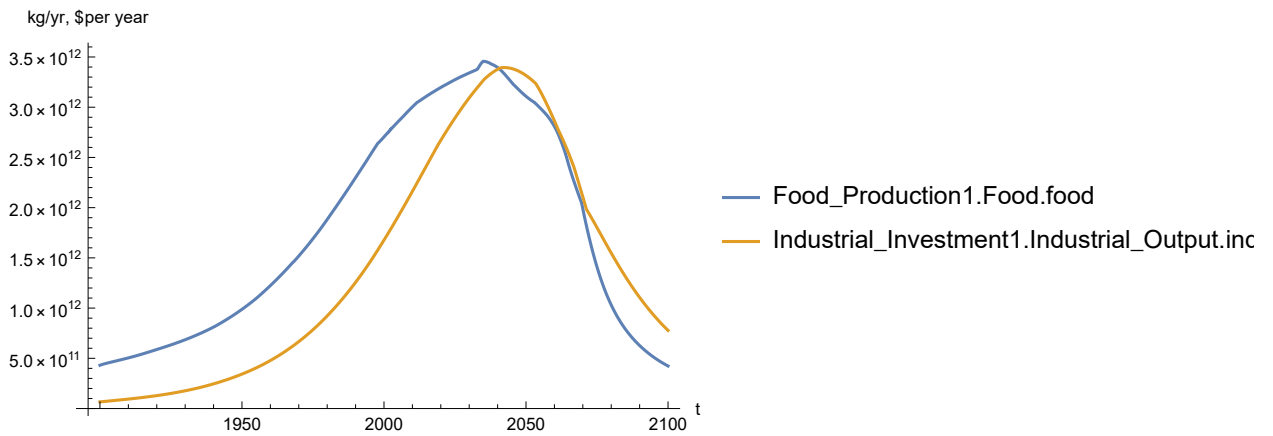
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

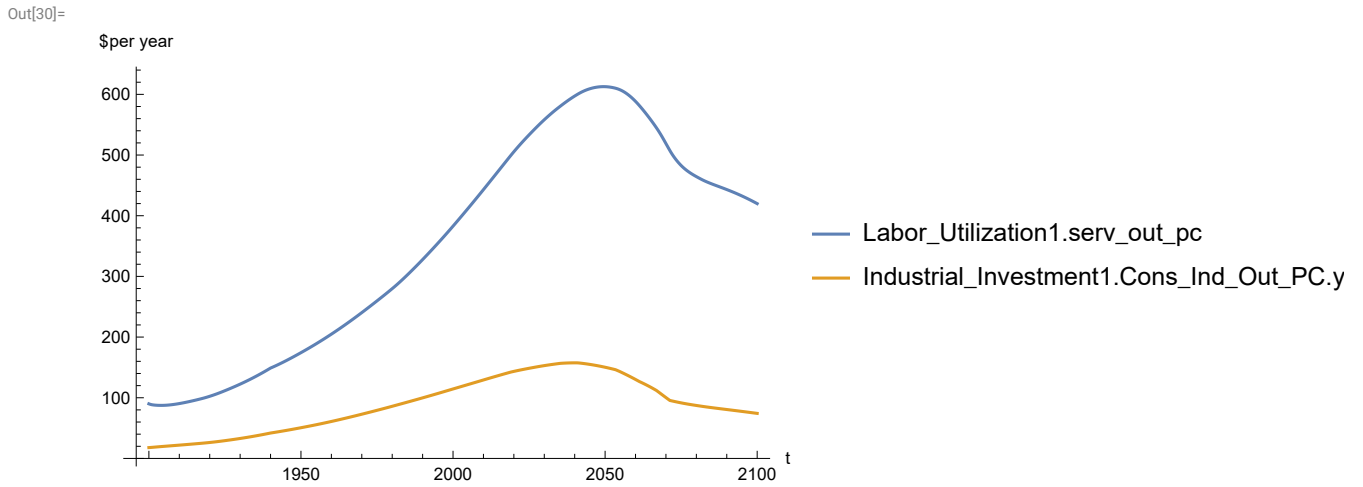
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

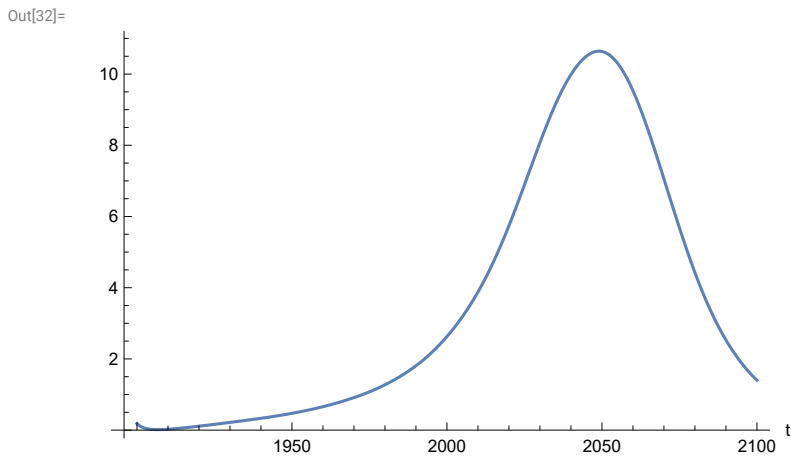


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 612.714
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



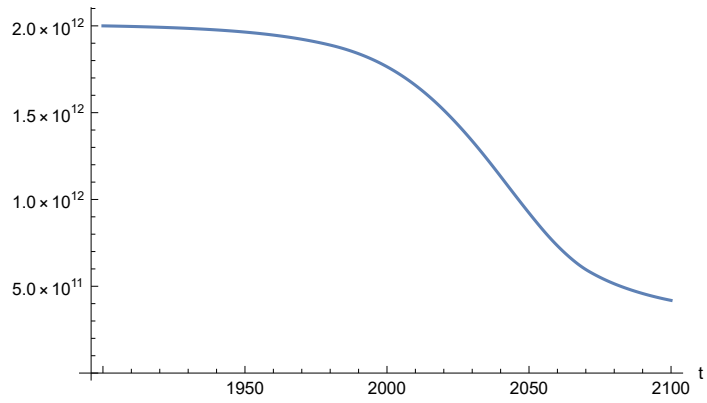
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.6416
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

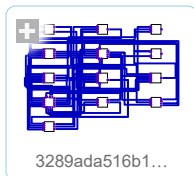


APPENDIX 4A2. LE/1.01, t_policy_year =2002. Baseline Scenario 8, Experiment 4A2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=


```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

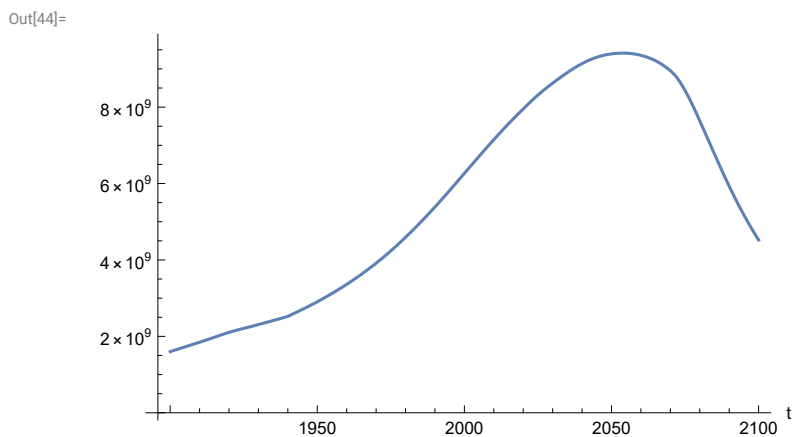
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: W3289ada516b14f27bbd1f03329405cdc
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

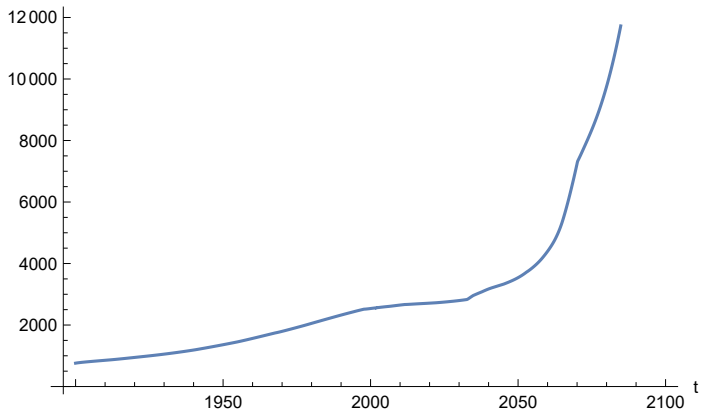
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.4135 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

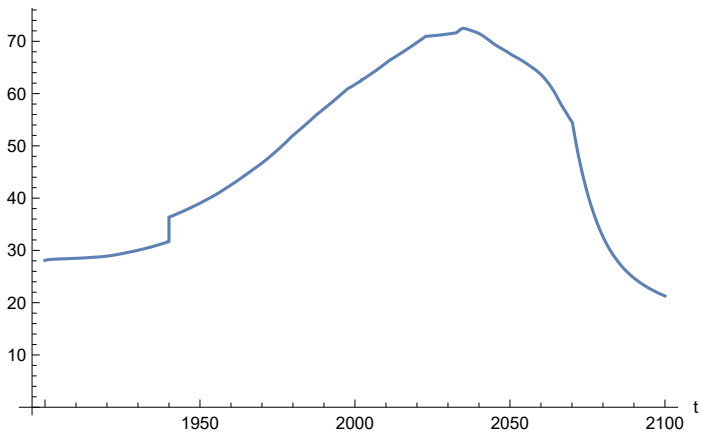
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

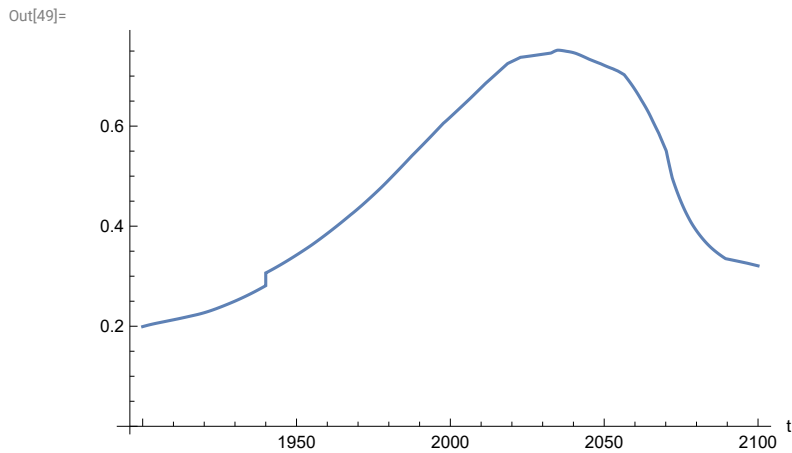
Out[47]=



In[48]=

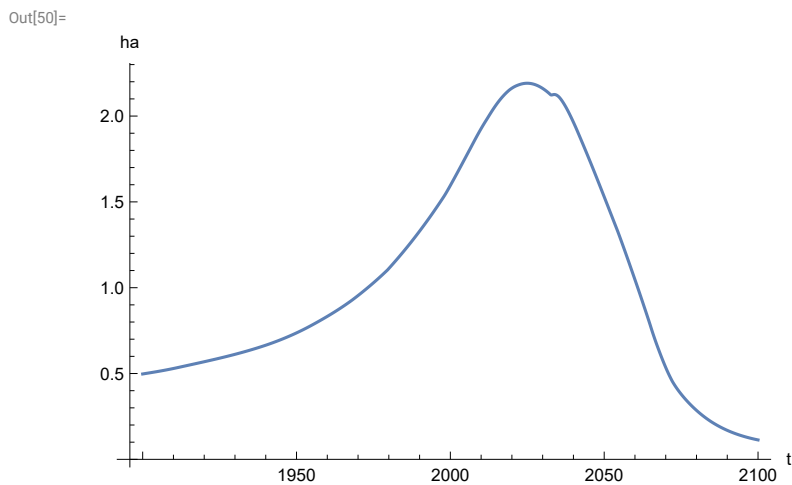
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

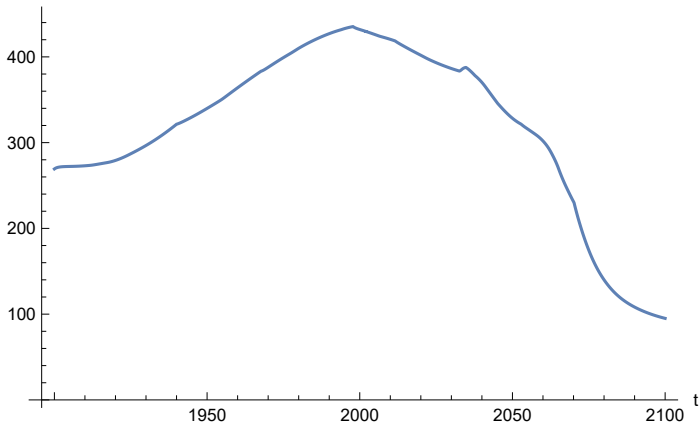
```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

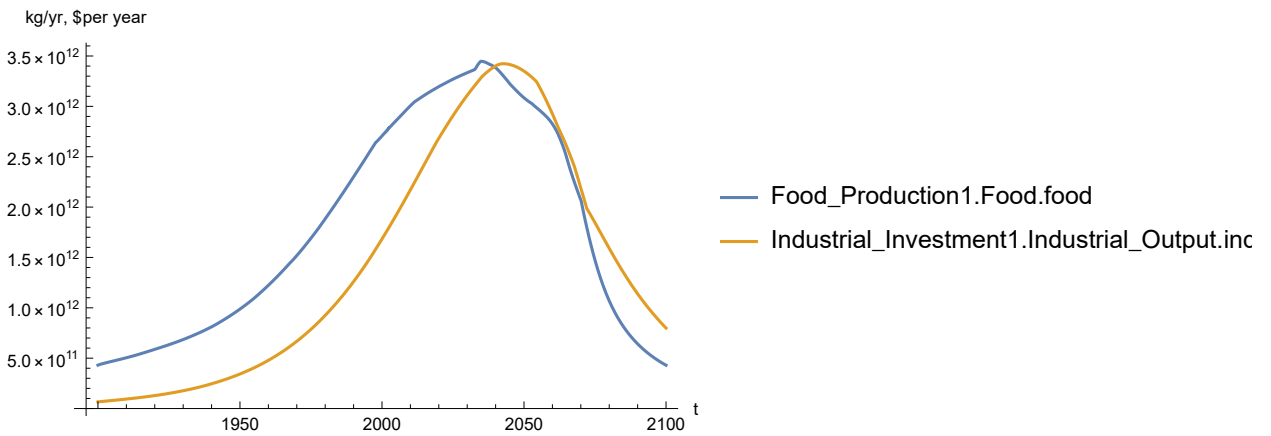
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

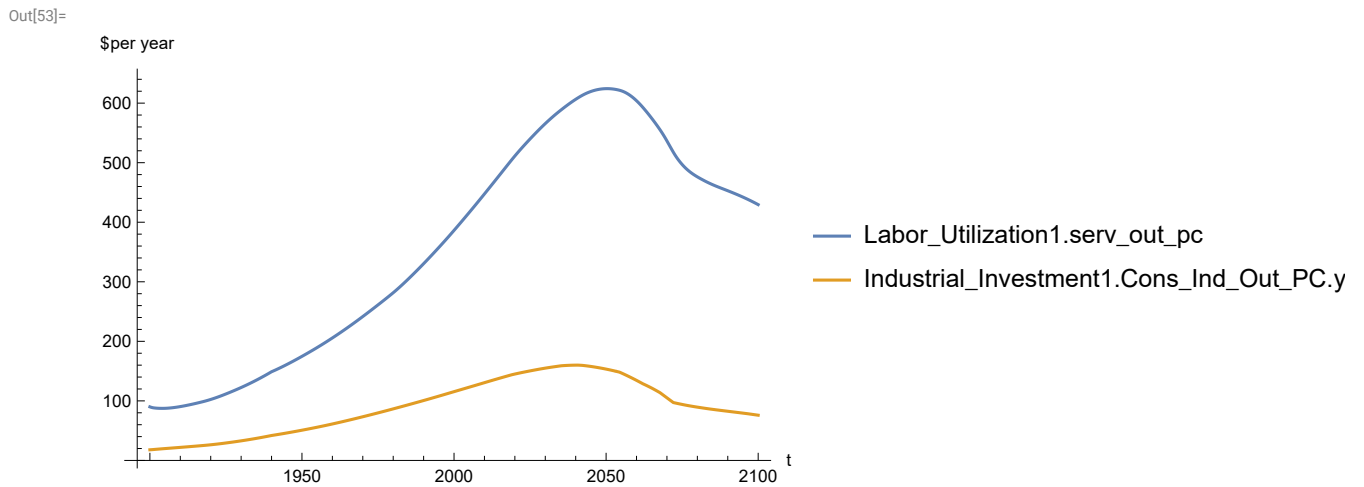
In[52]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

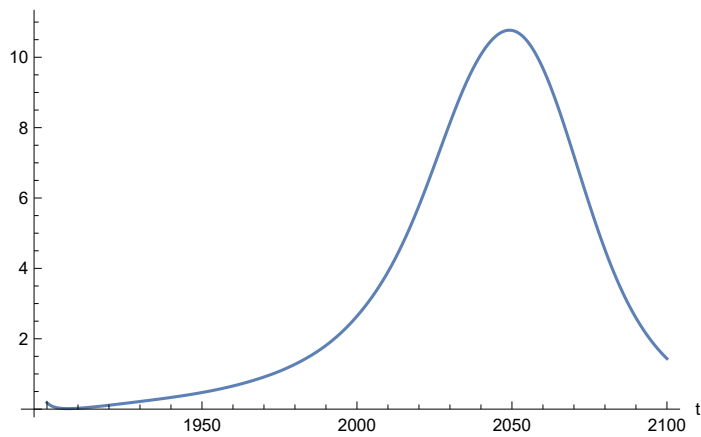


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 624.324
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



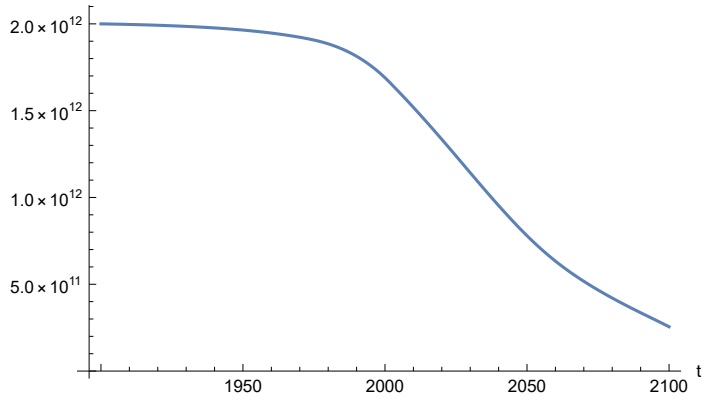
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.769
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 4B1. BENCHMARK SCENARIO 8, Experiment 4B1. $LE = LE/1.03$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1430 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

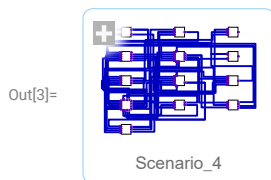
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

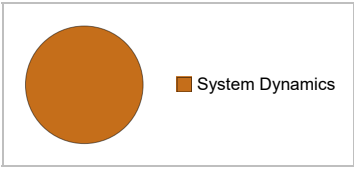
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 4.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_4"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_4
	D	More accessible non-recoverable natural resources, pollution control, and land yield enhancement
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

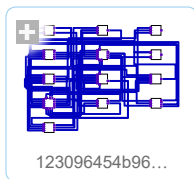
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```


```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[19]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

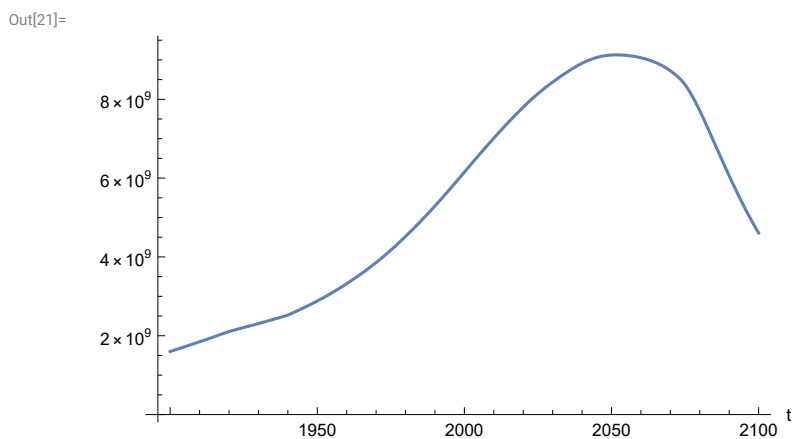
Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

```
Out[20]= SystemModelSimulationData [  Model: W123096454b96490c91a3692ef6bab87c
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

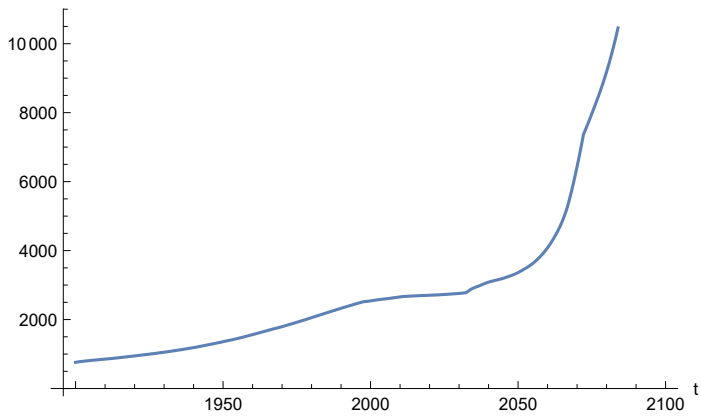
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.12717 × 109
```

```
Minimum is 1.6 × 109
```

```
In[23]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

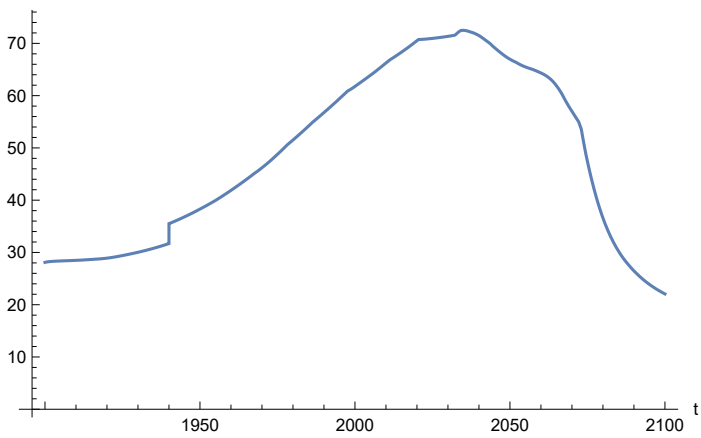
Out[23]=



Plot life expectancy, years.

```
In[24]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

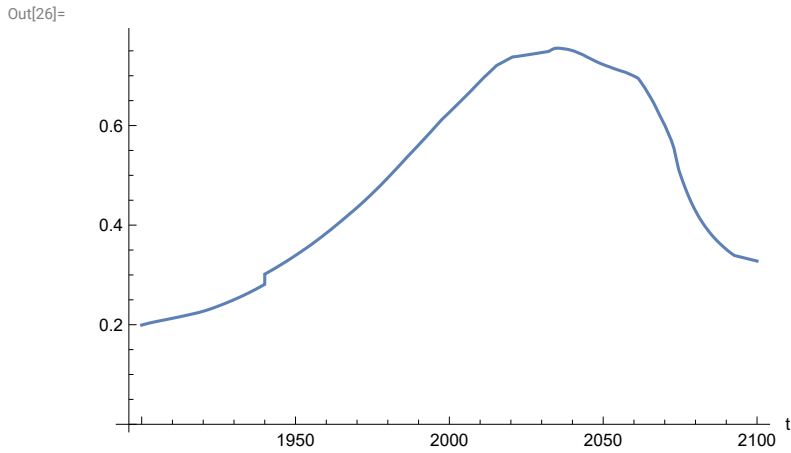
Out[24]=



In[25]=

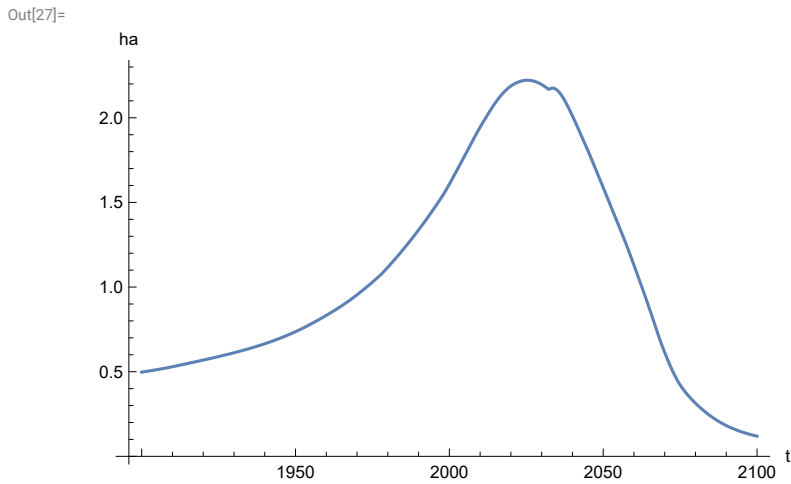
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

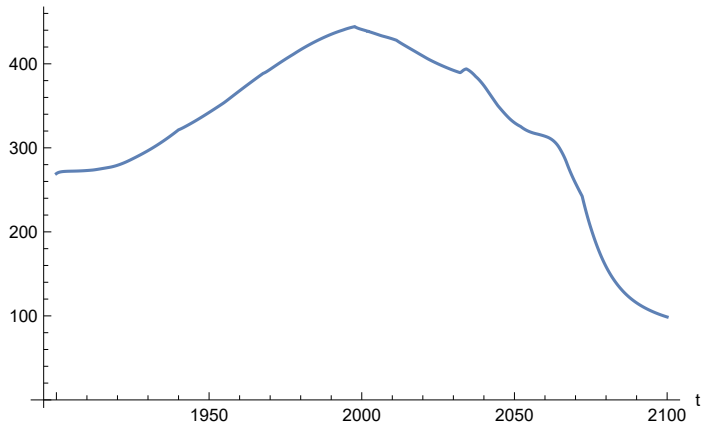
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

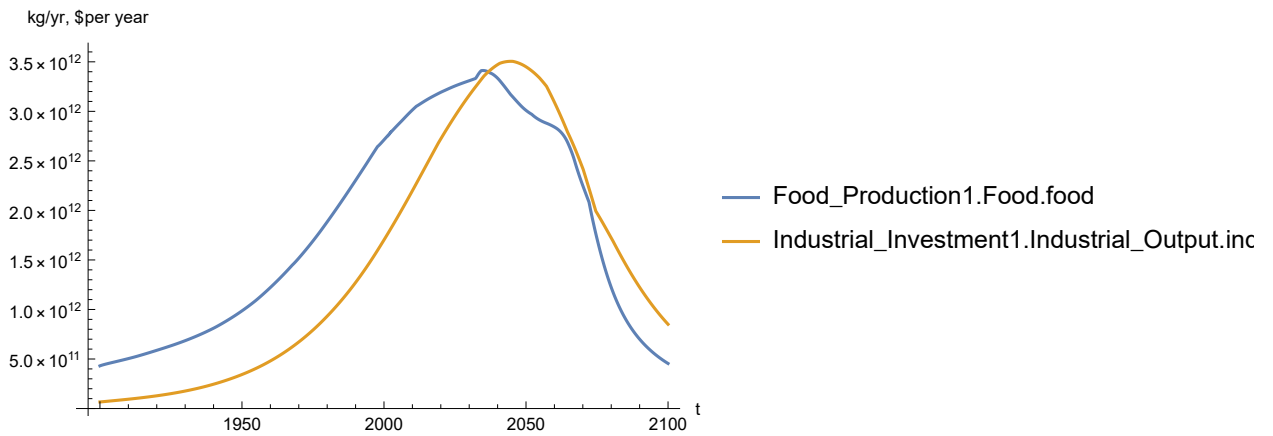
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

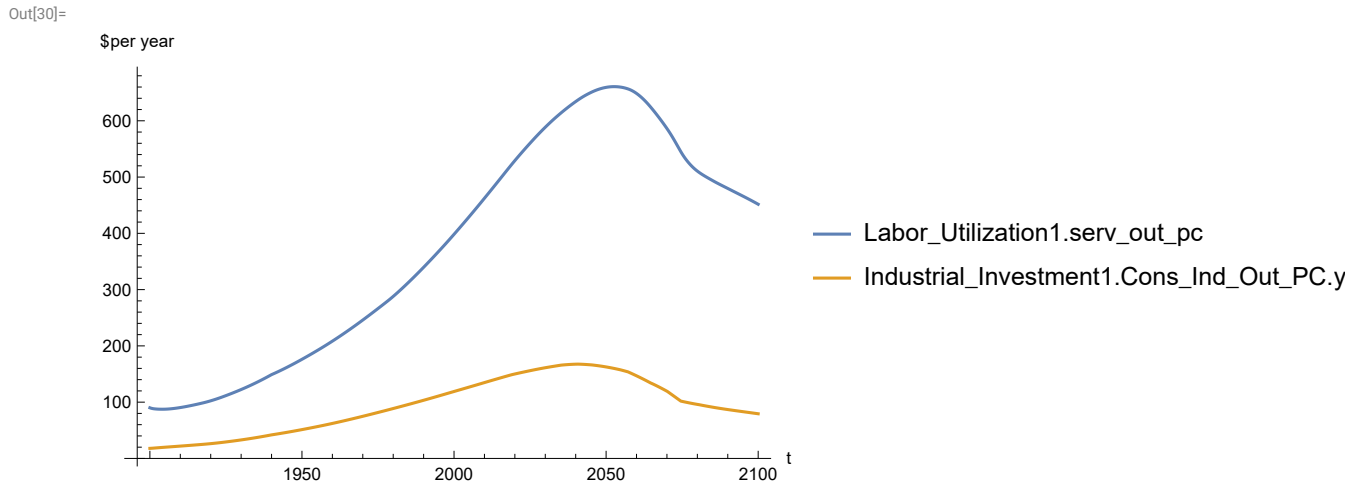
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

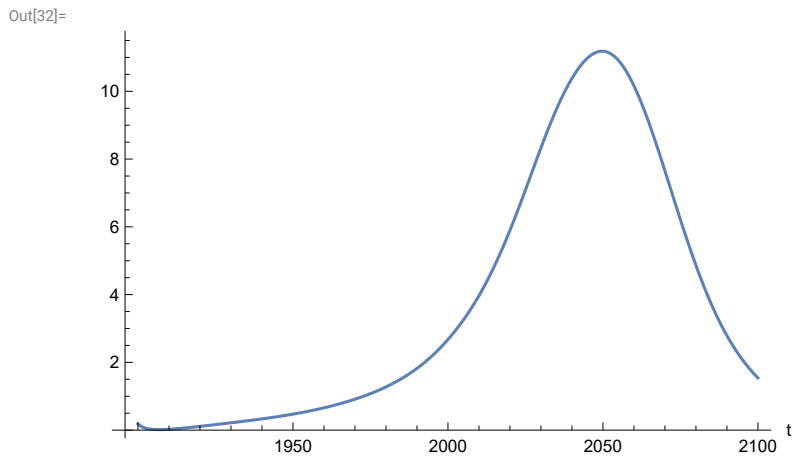


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 660.68
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



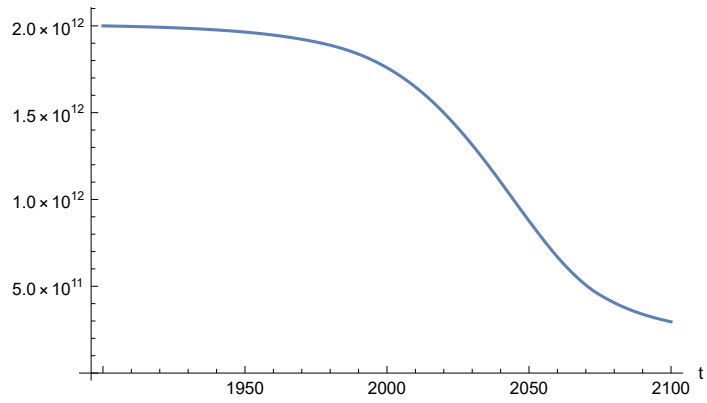
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.1833
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

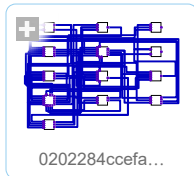


APPENDIX 4B2. LE/1.05, t_policy_year = 2002. Baseline Scenario 8, Experiment 4B2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=


```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

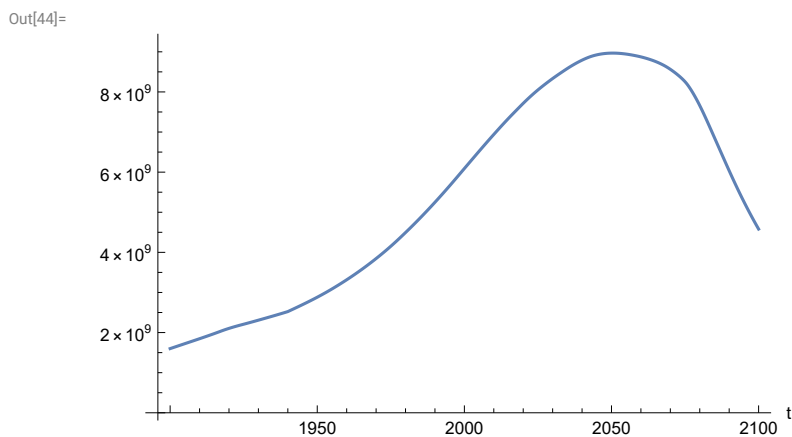
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: W0202284ccef44eb9ad9a892454647ce8
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

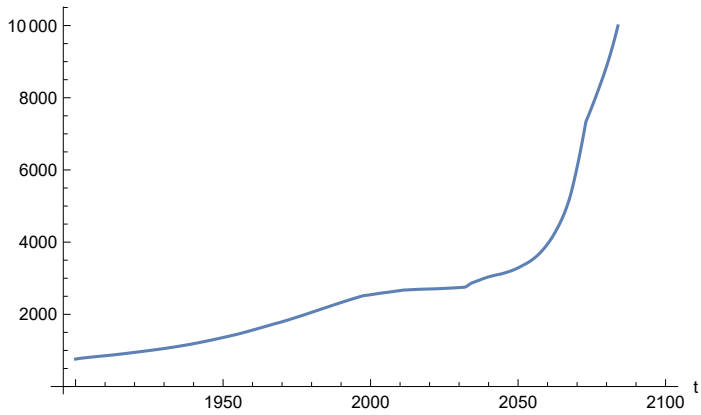
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.96777 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

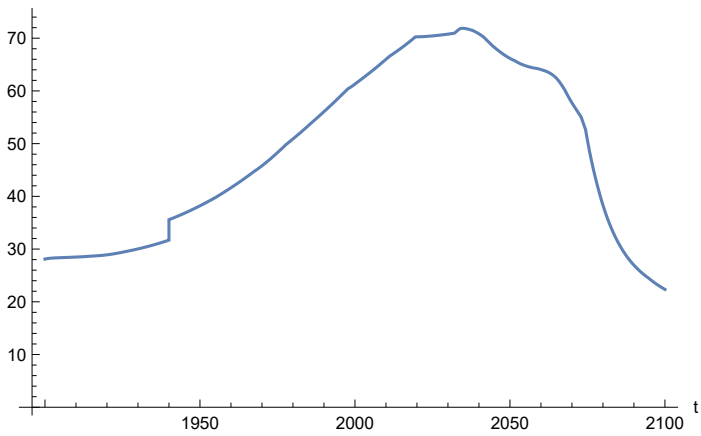
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

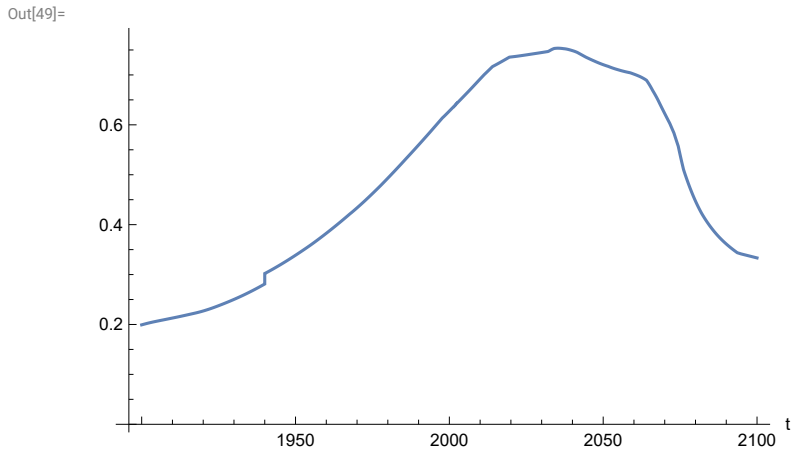
Out[47]=



In[48]=

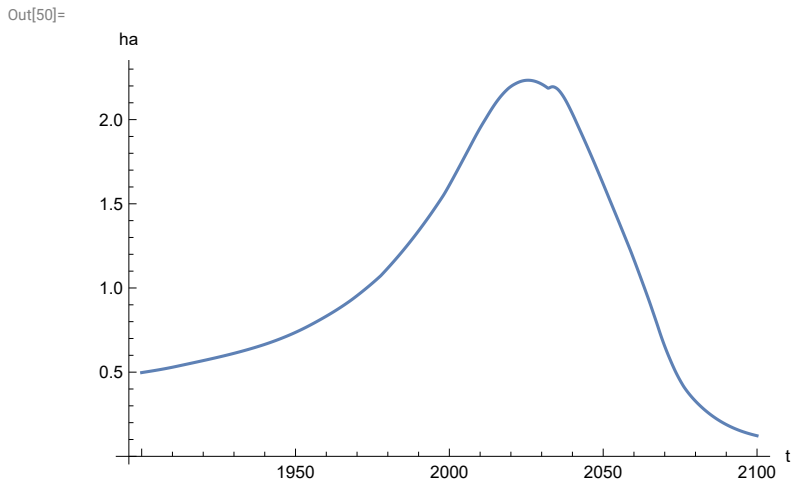
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

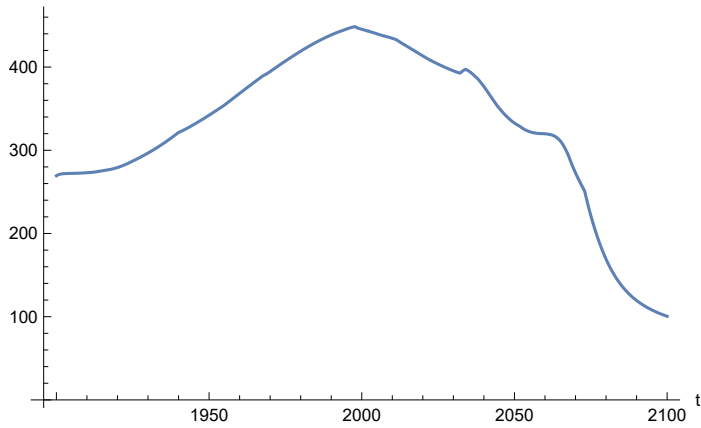
```
In[50]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

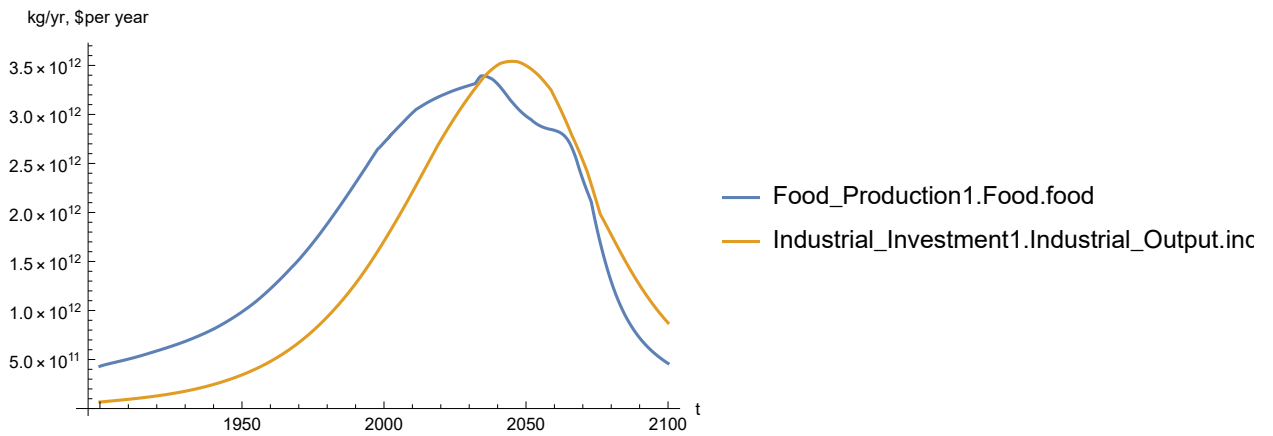
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[52]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

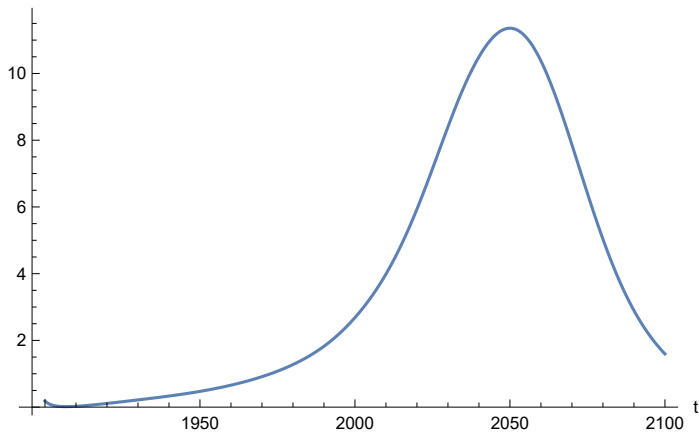


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 681.619
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



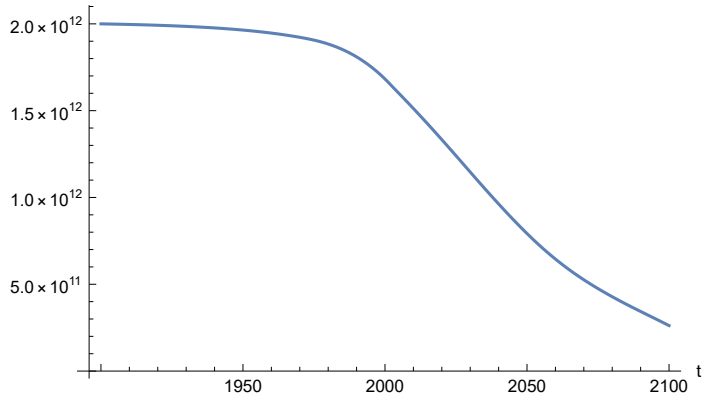
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.3566
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 4C1. BENCHMARK SCENARIO 8, Experiment 4C1. $LE = LE/1.1$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1230 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

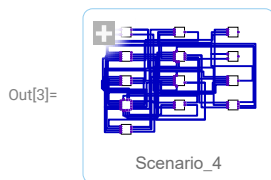
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

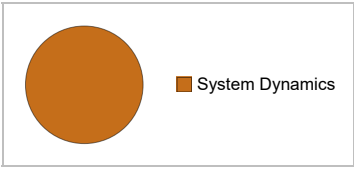
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 4.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_4"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_4
	D	More accessible non-recoverable natural resources, pollution control, and land yield enhancement
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

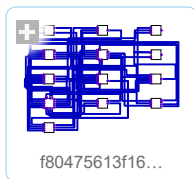
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

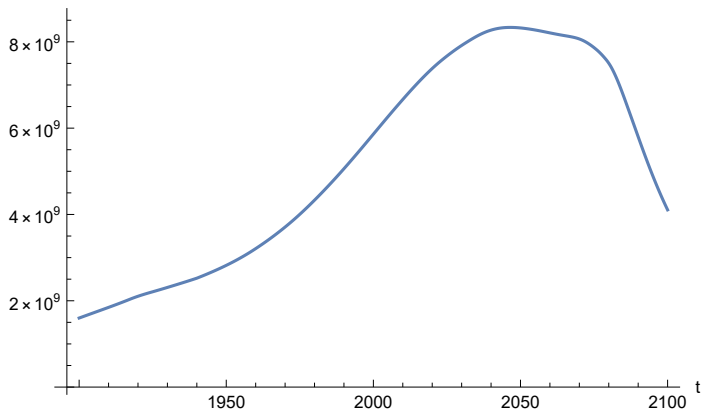
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Wf80475613f164827858bc80166594a49
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

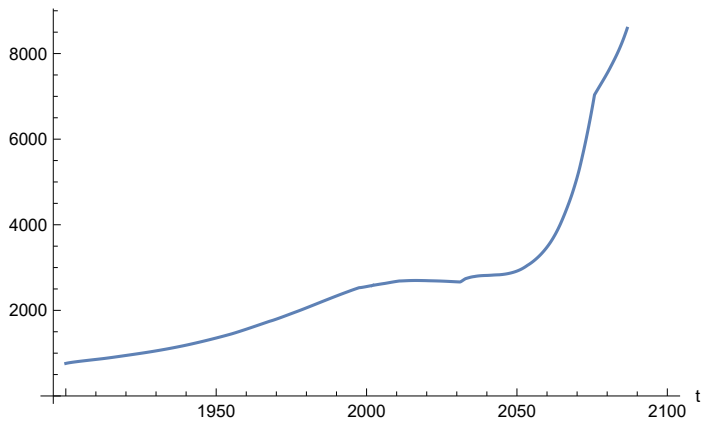
```
In[22]:= MinAndMax[basesim [{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.33389 × 109
```

```
Minimum is 1.6 × 109
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

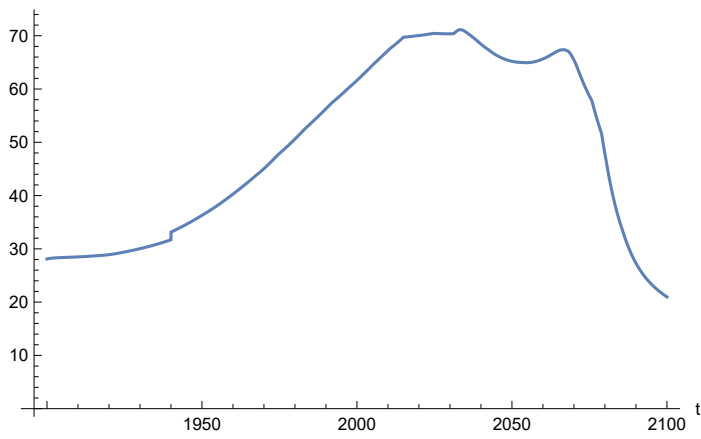
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

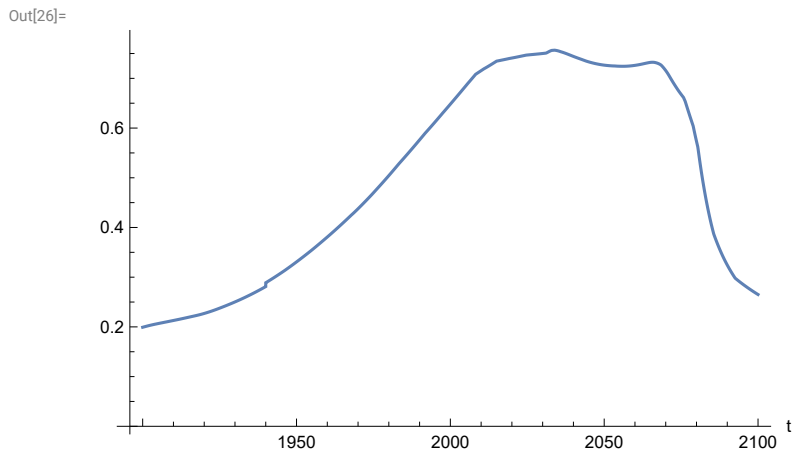
Out[24]=



In[25]:=

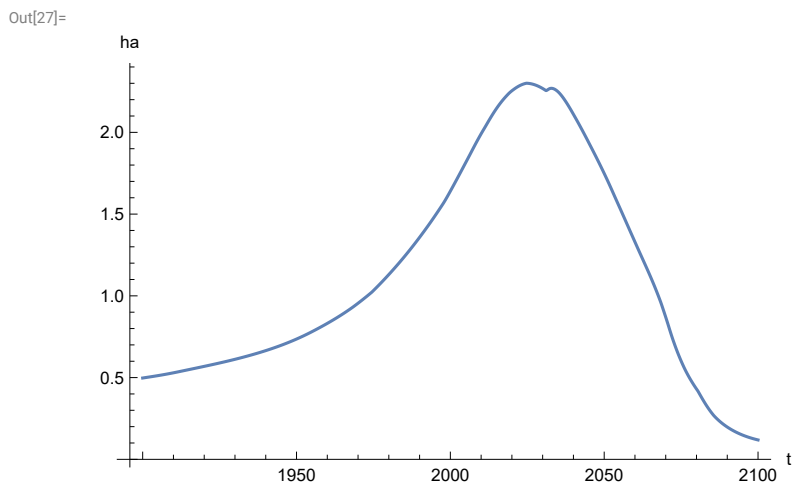
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

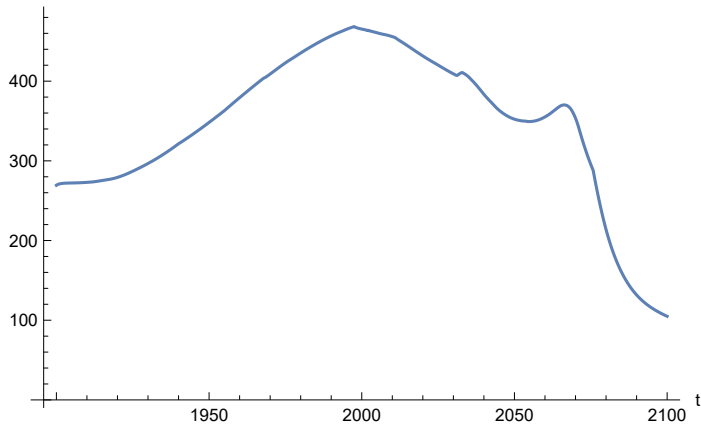
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

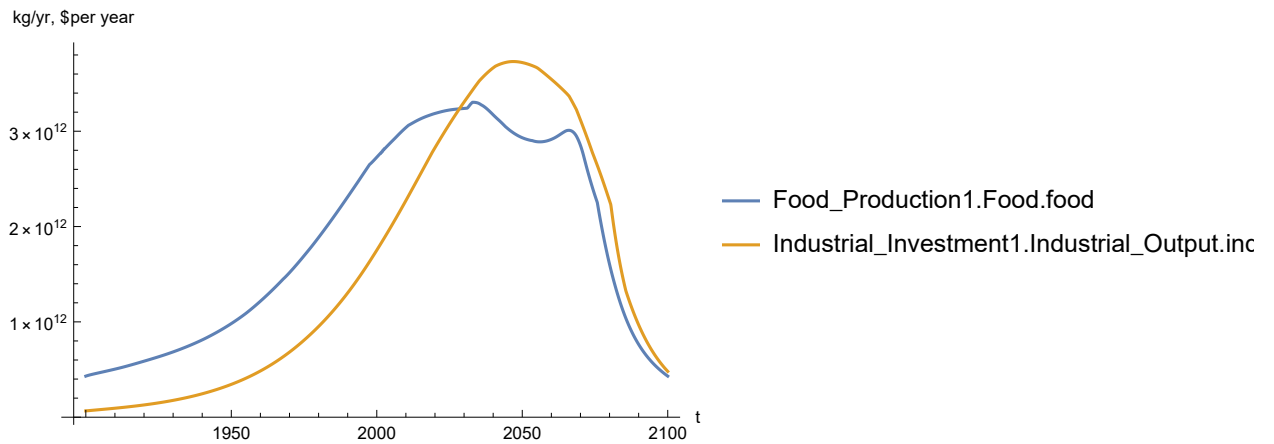
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

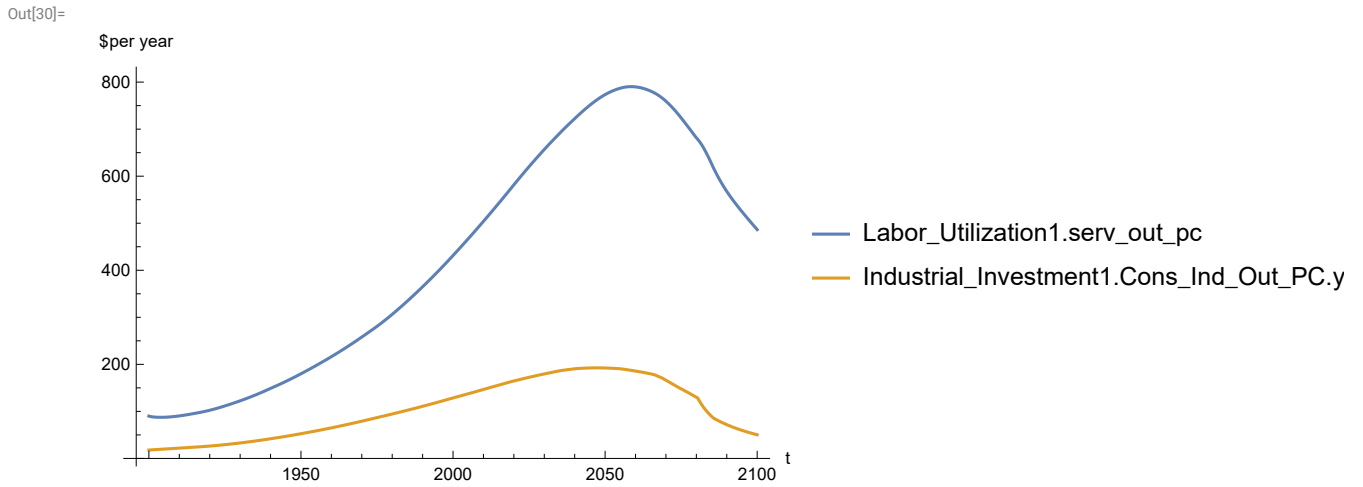
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

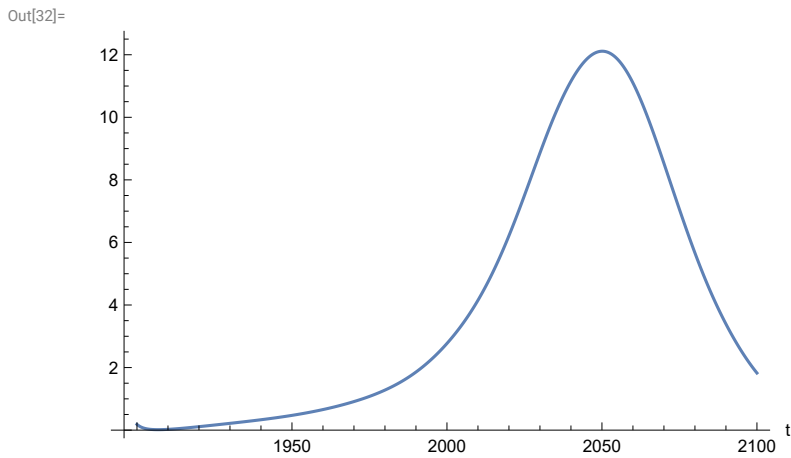


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 790.332
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

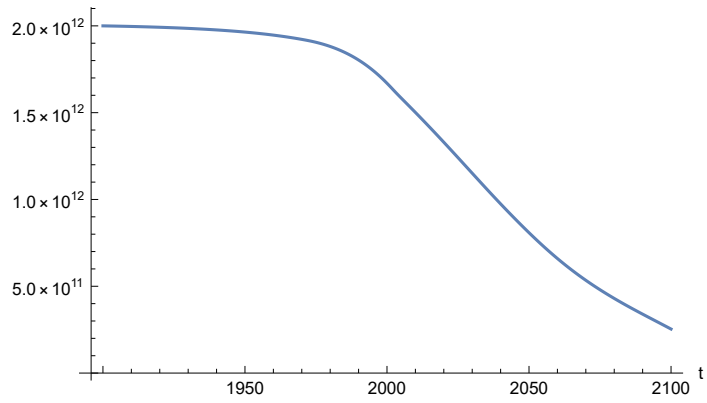


Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 12.1128
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[ ]:=
```



APPENDIX 53. BENCHMARK SCENARIO 5, Experiment 53. $t_{policy_year} = 2002$.

Last modified: 25 July 2022/0730 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

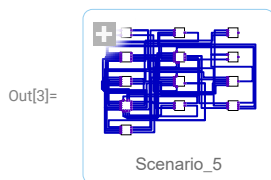
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

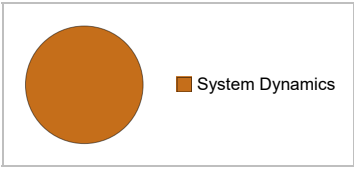
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Benchmark Scenario 5.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_5"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	M	SystemDynamics.WorldDynamics.World3.Scenario_5
	D	More accessible non-recoverable natural resources, pollution control, land yield enhancement, and erosion
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show the default value of `t_policy_year`.

```
In[5]:= SystemModel[mysim][{"ParameterValues", "t_policy_year"}]
```

```
Out[5]= {t_policy_year → 2002}
```

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

```
In[6]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[7]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[8]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[9]:= SystemModel[mysim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute scenario and plot various variables

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

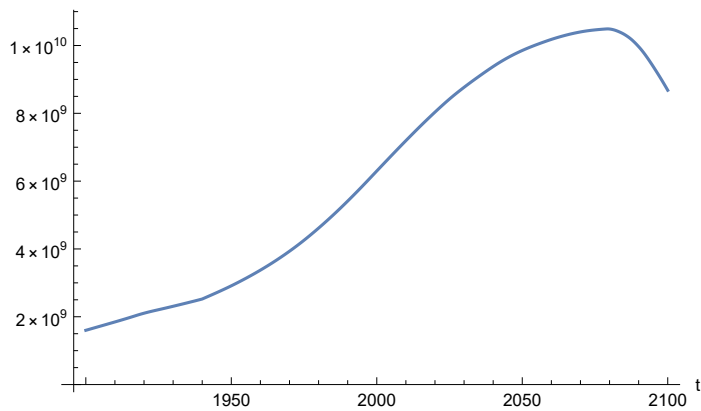
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Scenario_5
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

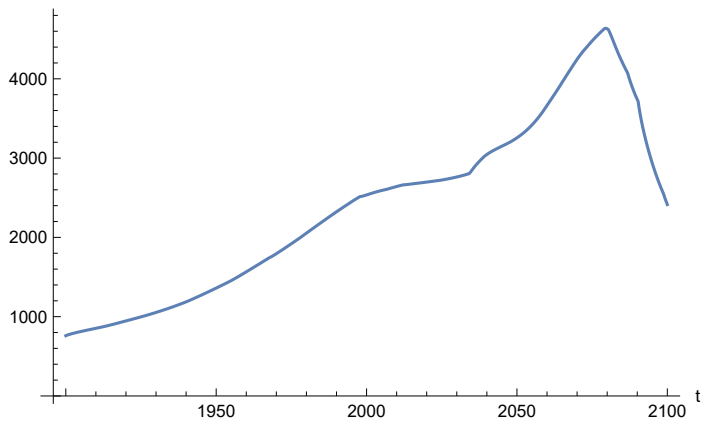
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 1.04901 × 1010
```

```
Minimum is 1.6 × 109
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

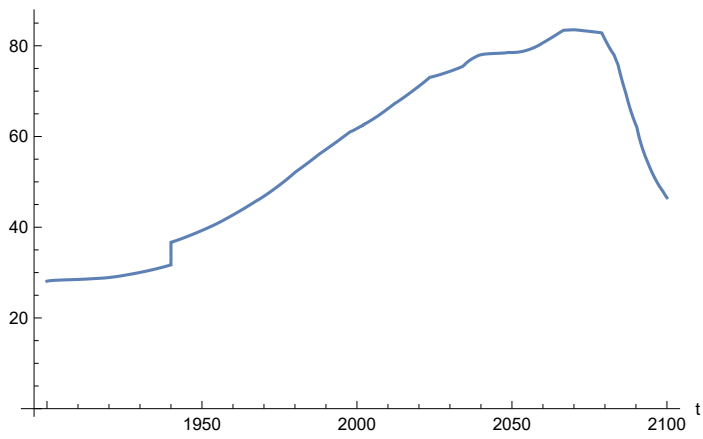
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

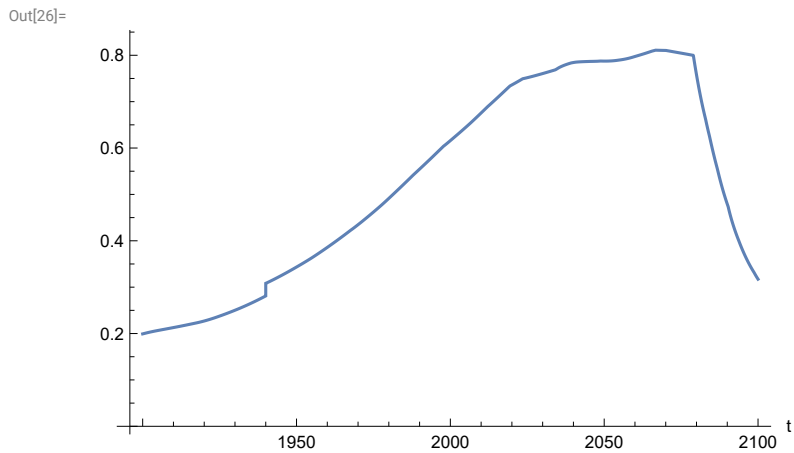
Out[24]=



In[25]:=

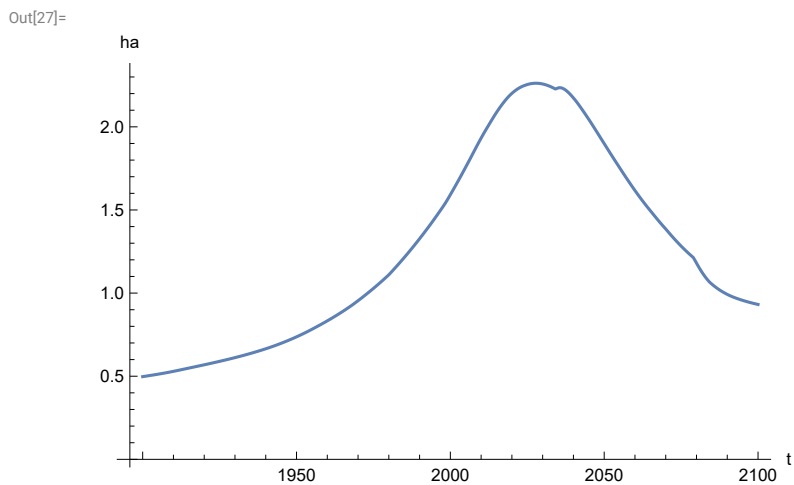
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



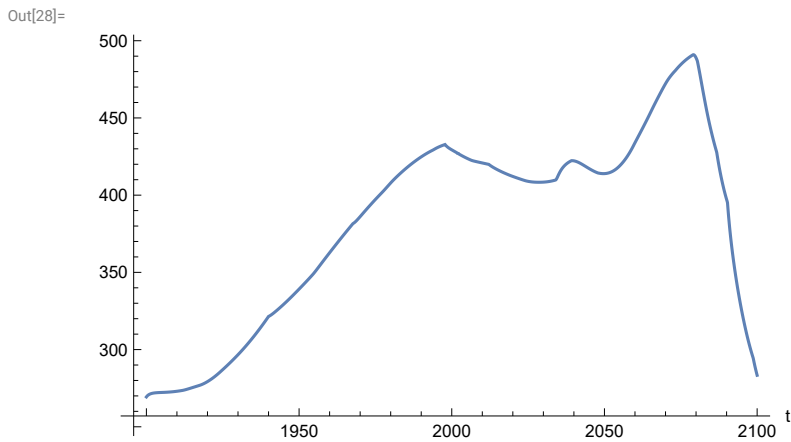
Plot per capita ecological footprint, hectares.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



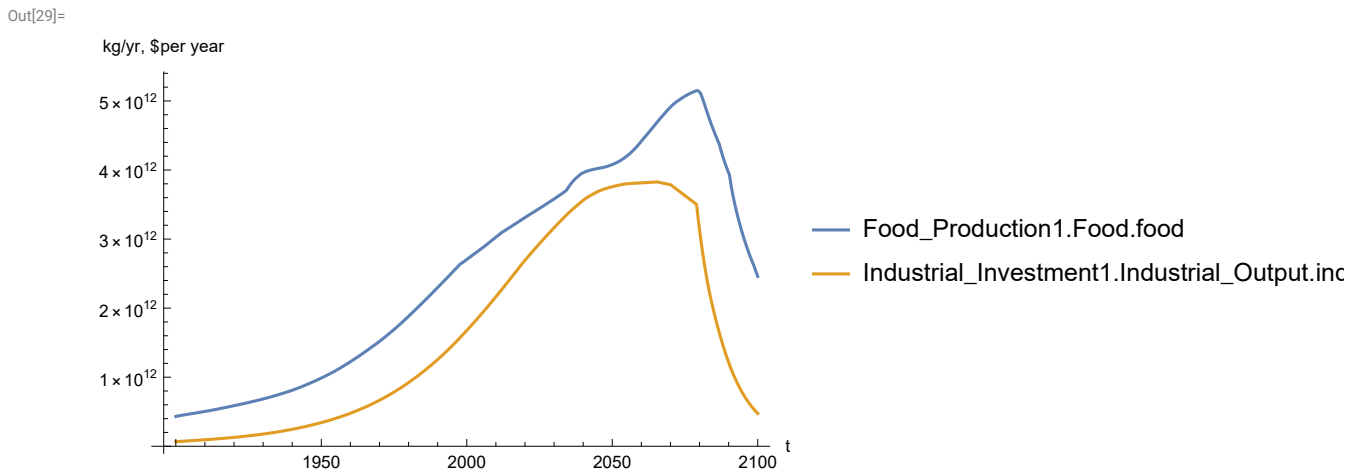
Plot food production per capita (kg/year).

```
In[28]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



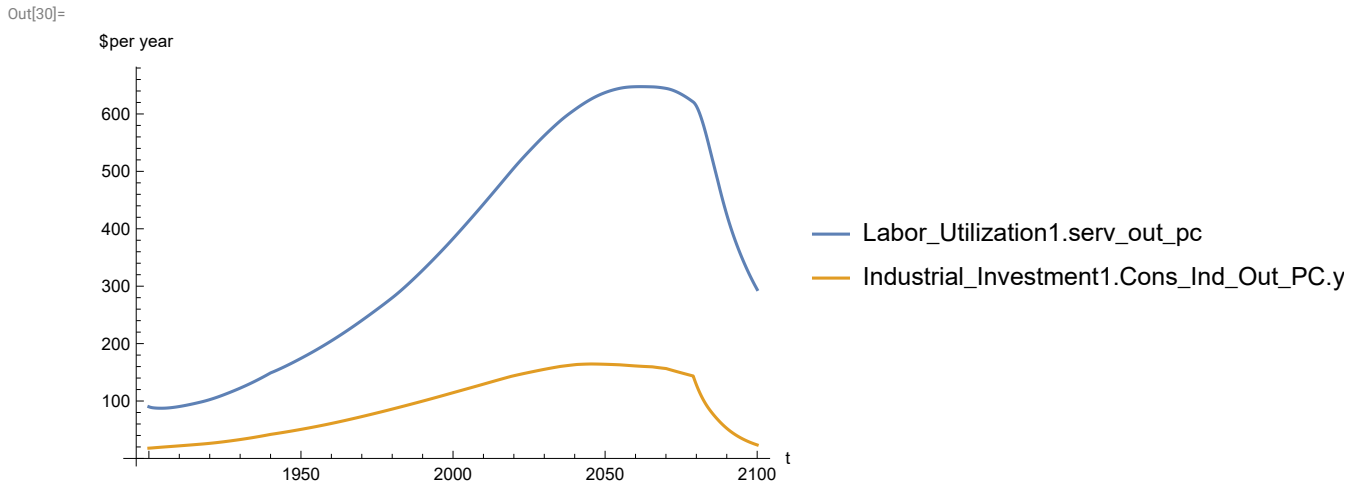
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



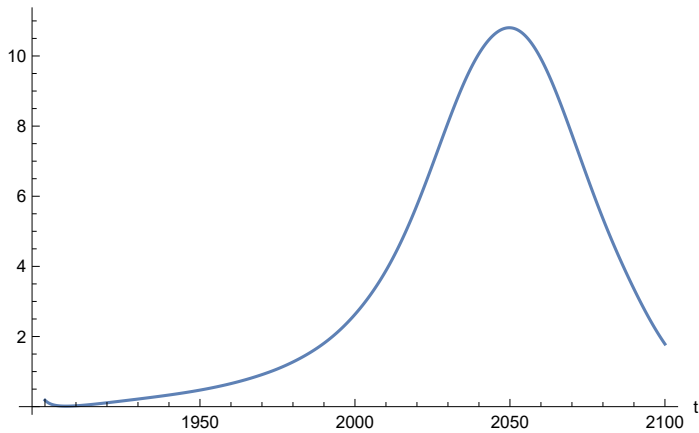
Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 647.557
Minimum is 87.4451
```

Find max and min of y values.

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[32]=
```



Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

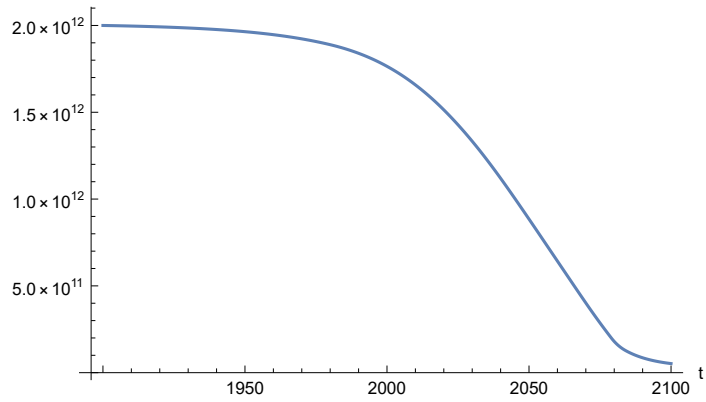
Maximum is 10.8051

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

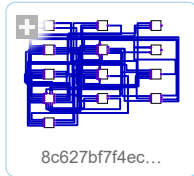


APPENDIX 54. $t_policy_year = 1970$, Benchmark Scenario 5, Experiment 4

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.


```
In[35]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[35]=
```



```
In[36]:= testsim1970 = SystemModelSimulate[newmysim1970]
```

```
Out[36]=
```

```
SystemModelSimulationData [  Model: W8c627bf7f4ec4365accb8f81c524f5e7  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of t_policy_year .

```
In[37]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
```

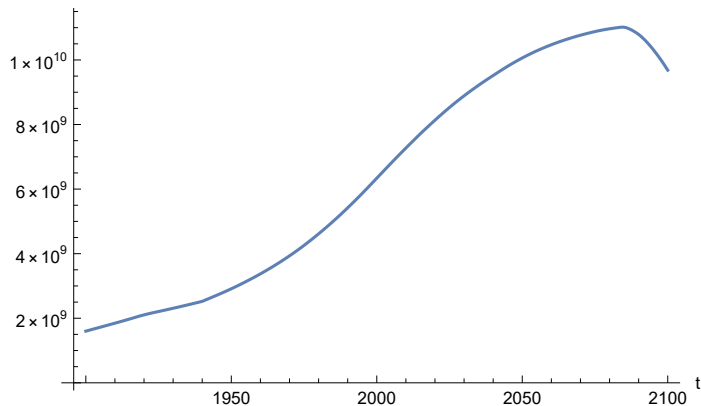
```
Out[37]=
```

```
{t_policy_year → 1970}
```

Plot the world population, people.

```
In[38]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
```

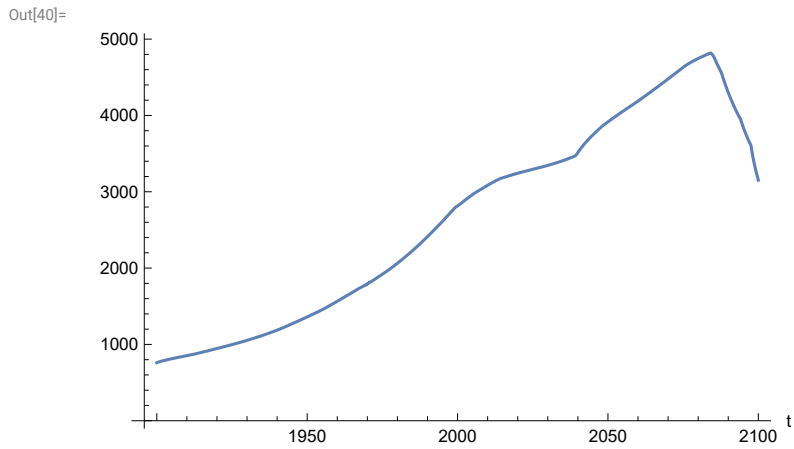
```
Out[38]=
```



Find max and min of y values.

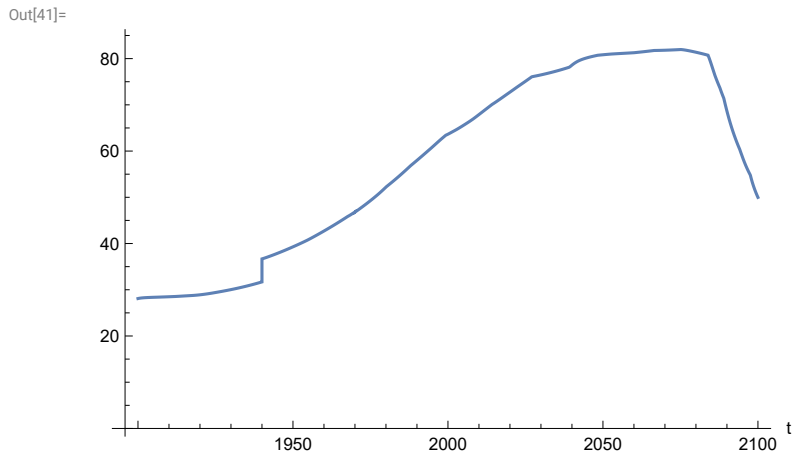
```
In[39]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $1.10166 \times 10^{10}$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[40]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
```



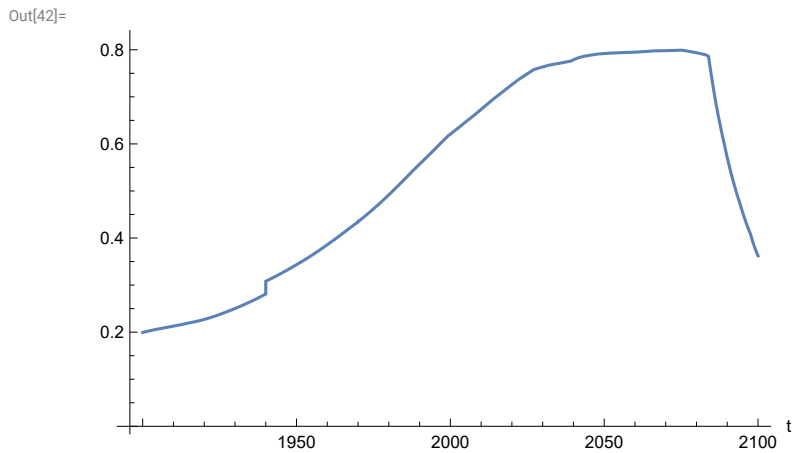
Plot life expectancy, in years.

```
In[41]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
```



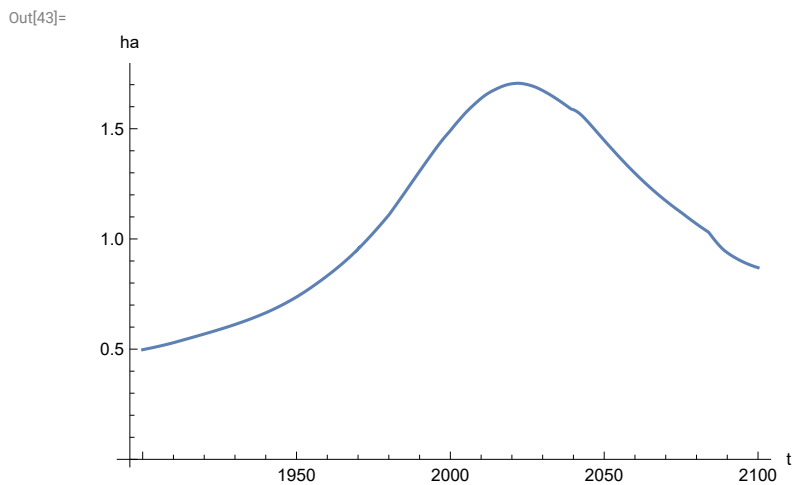
Plot the human welfare index.

```
In[42]:= SystemModelPlot[testsim1970,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



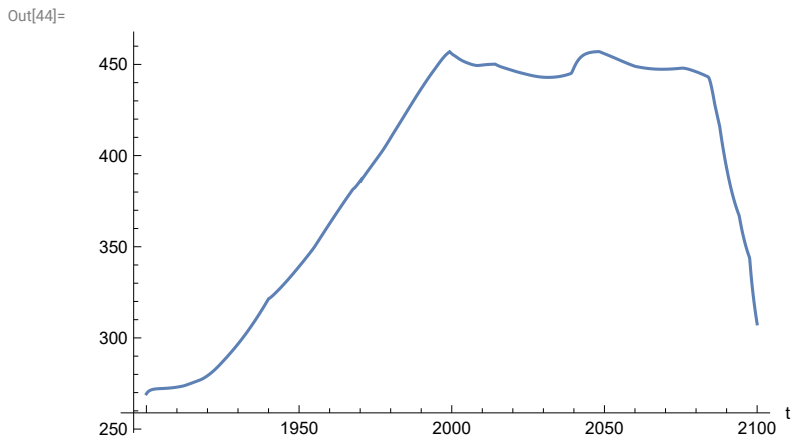
Plot the human ecological footprint, in hectares.

```
In[43]:= SystemModelPlot[testsim1970,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



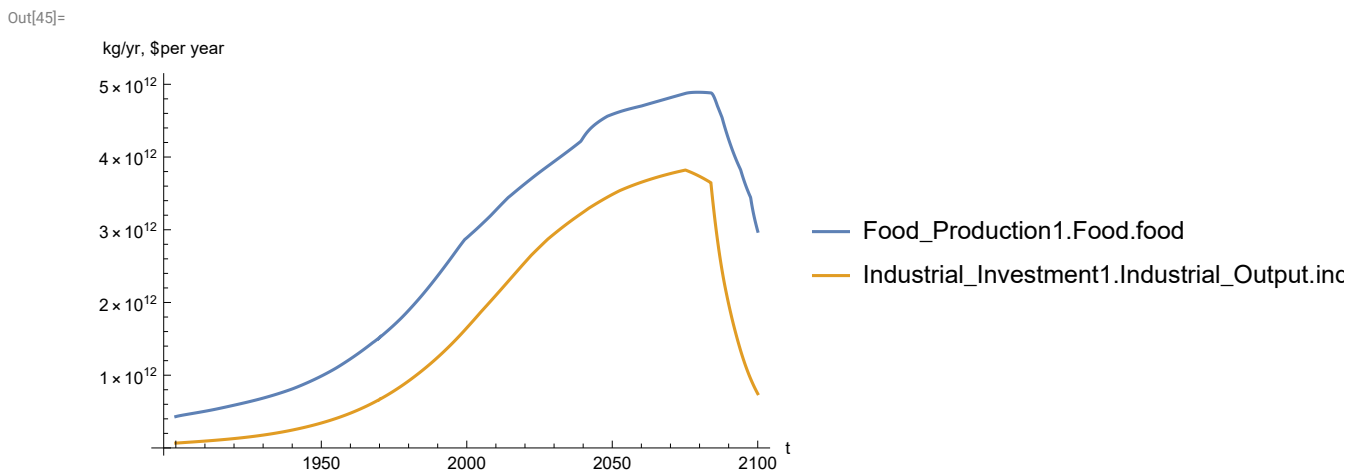
Plot per capita food production, kg/year.

```
In[44]:= SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/yr) and industrial output (in dollars).

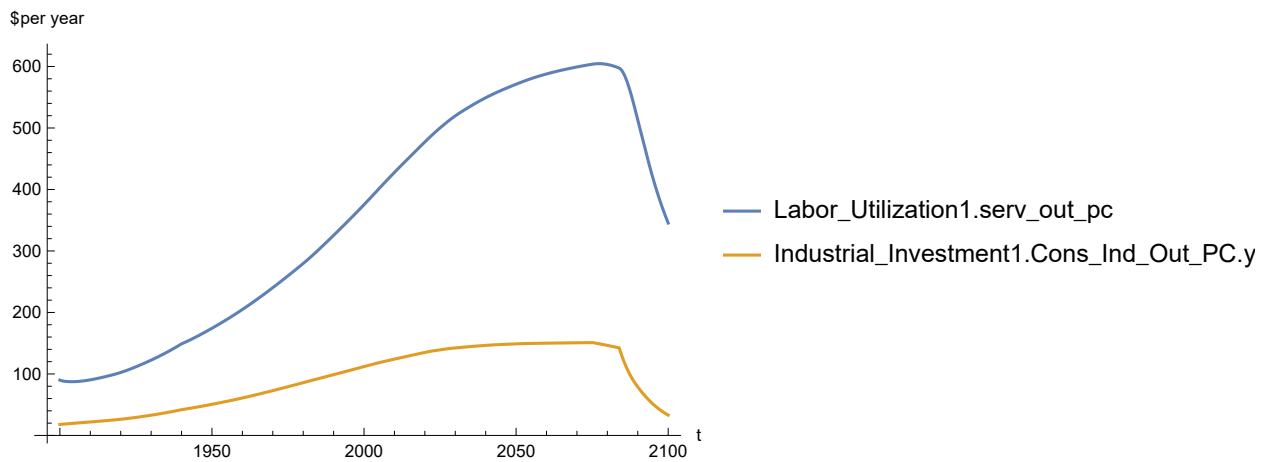
```
In[45]:= SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[46]:= SystemModelPlot[testsim1970,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[46]=



Find max and min of y values.

```
In[47]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

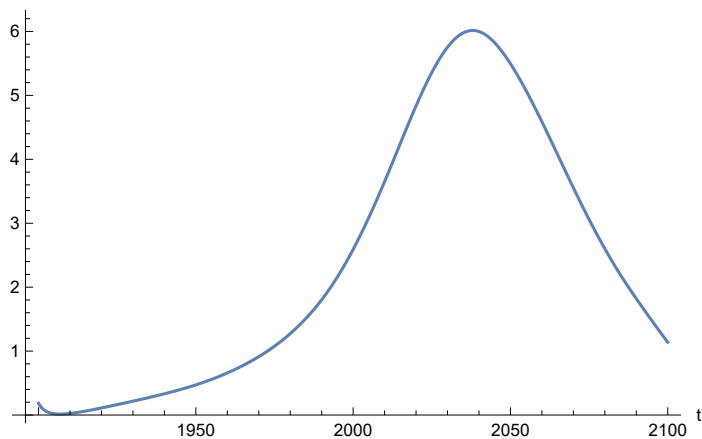
Maximum is 604.631

Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[48]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[48]=



Find max and min of y values.

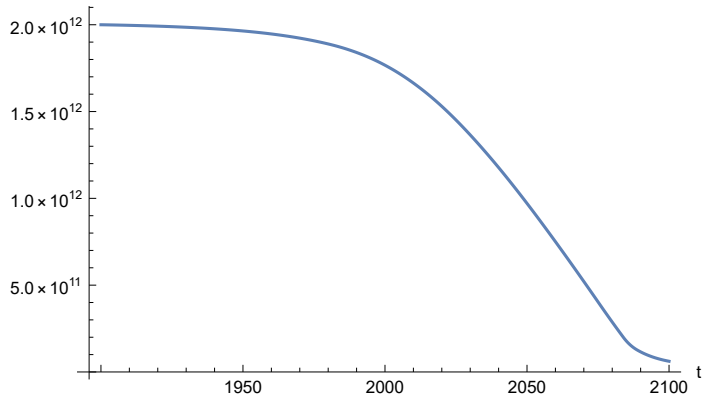
```
In[49]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 6.01532

Minimum is 0.0150765

Plot non-renewable resources remaining.

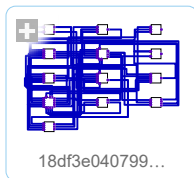
```
In[50]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[50]=
```



APPENDIX 55. Benchmark Scenario 5, $t_{\text{policy_year}} = 2025$. Experiment 55.

Change the value of the air pollution effect multiplier switch time $t_{\text{policy_year}}$, to calendar year 2025, and execute the resulting scenario, plotting the variables shown in Figure 2.

```
In[51]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
Out[51]=
```



```
In[52]:= testsim = SystemModelSimulate[newmysim]
Out[52]=
```

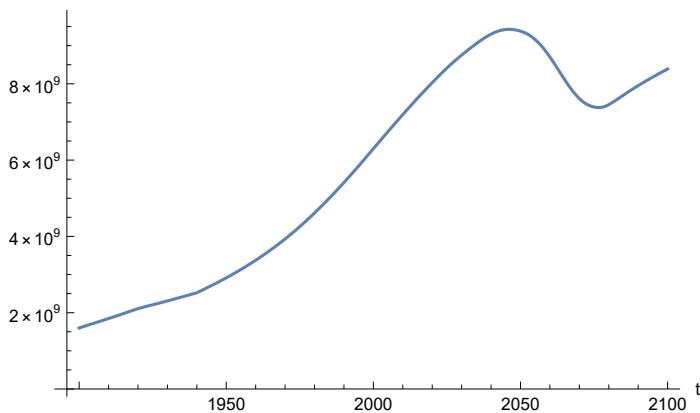
```
SystemModelSimulationData [ { Model: W18df3e04079940d0bb538906d7936e26
Time: 1.90 × 103 to 2.10 × 103 } ]
```

Show the value of $t_{\text{policy_year}}$.

```
In[53]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
Out[53]= {t_policy_year → 2025}
```

Plot the world population, people.

```
In[54]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[54]=
```

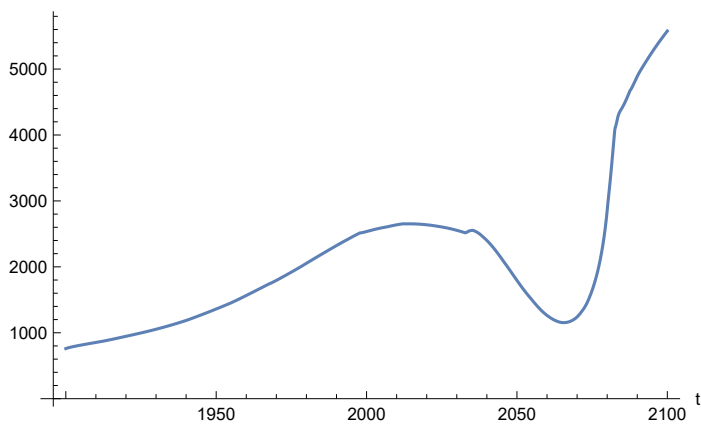


Find max and min of y values.

```
In[55]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.4281 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

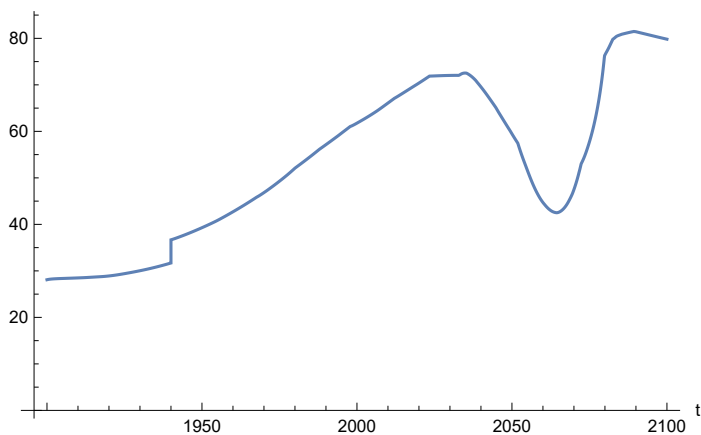
Plot land yield.

```
In[56]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[56]=
```



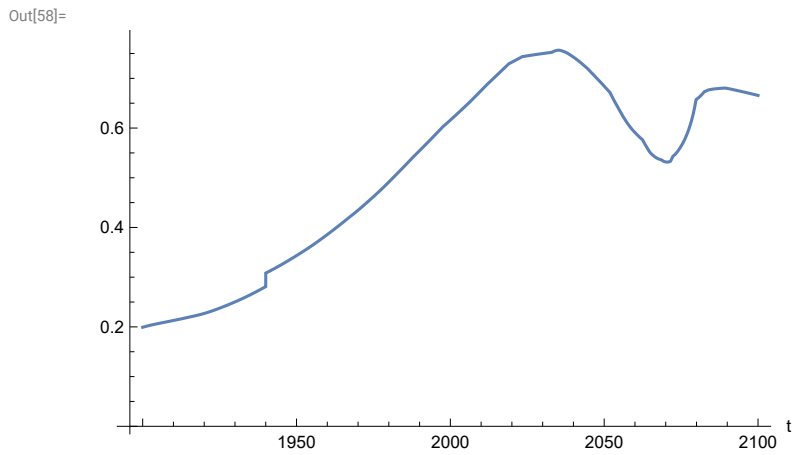
Plot life expectancy, in years.

```
In[57]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[57]=
```



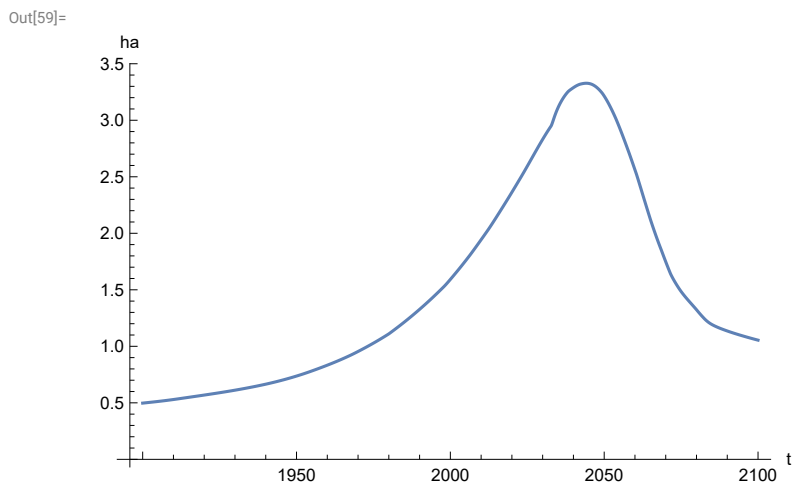
Plot the human welfare index.

```
In[58]:= SystemModelPlot[testsim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



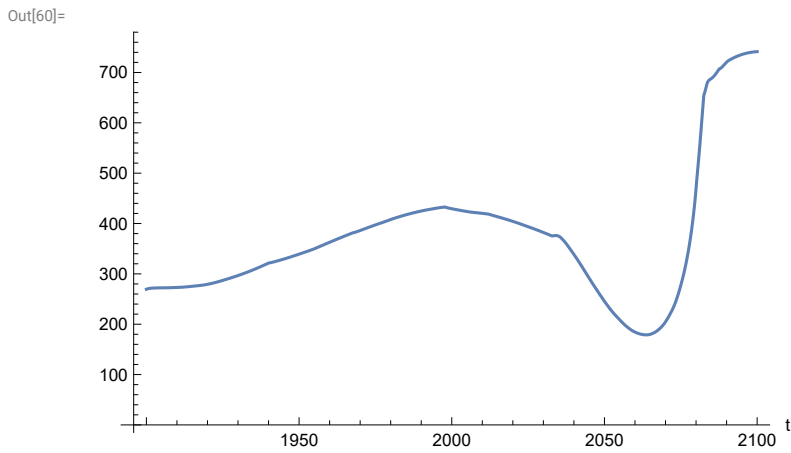
Plot the human ecological footprint, in hectares.

```
In[59]:= SystemModelPlot[testsim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



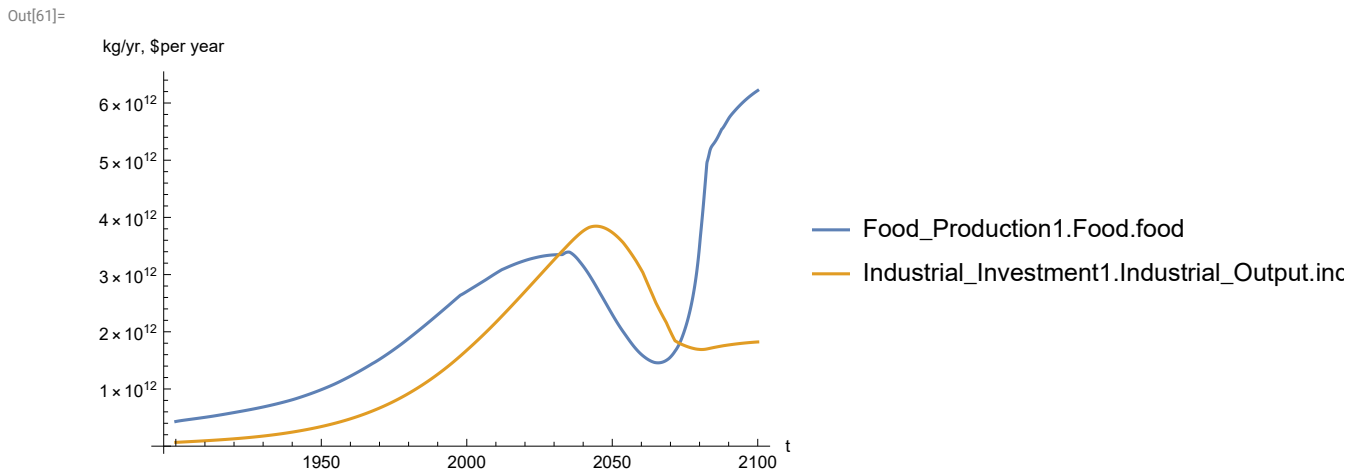
Plot per capita food production, kg/year.

In[60]:= **SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]**



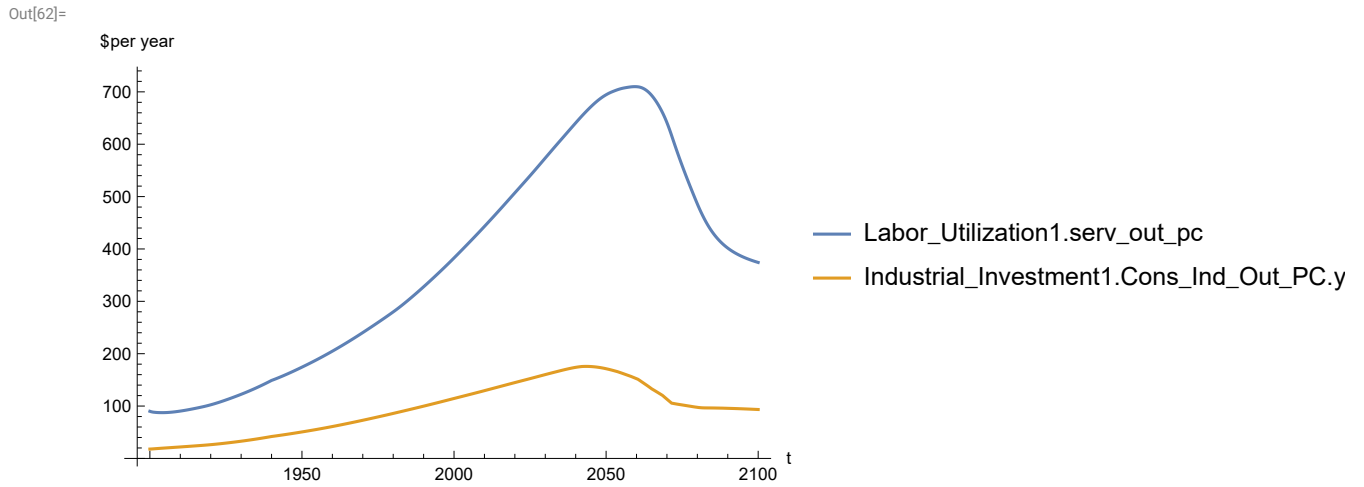
Plot total food production (kg/yr) and industrial output (in dollars).

In[61]:= **SystemModelPlot[testsim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**



Plot consolidated industrial output per capita (dollars/year).

```
In[62]:= SystemModelPlot[testsim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

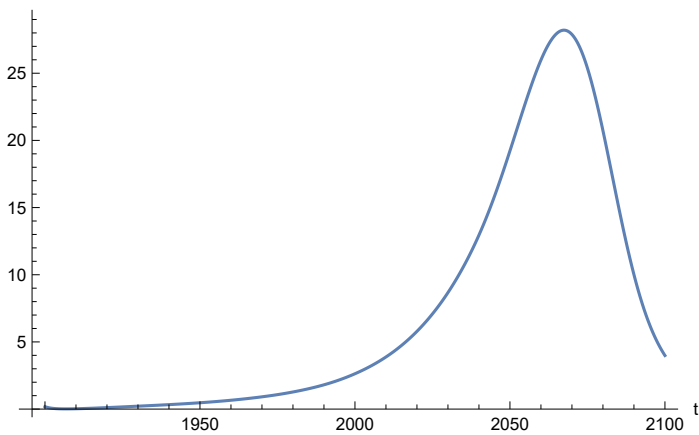


Find max and min of y values.

```
In[63]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 709.944
Minimum is 87.4451
```

Plot persistent pollution index (normalized to 1970 value).

```
In[64]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[64]=
```

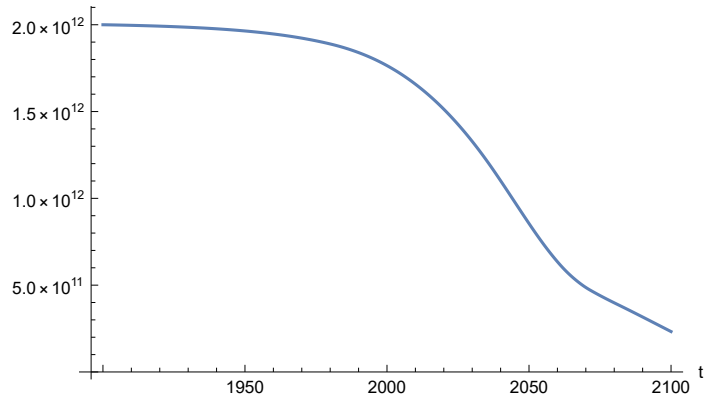


Find max and min of y values.

```
In[65]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 28.2044
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[66]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[66]=
```



APPENDIX 56. BENCHMARK SCENARIO 5, Experiment 56. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 25 July 2022/0830 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

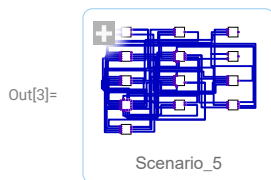
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

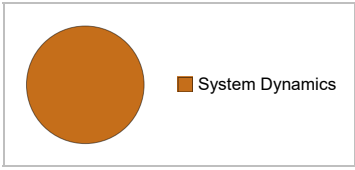
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 5.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_5"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_5
	Description	More accessible non-recoverable natural resources, pollution control, land yield enhancement, and erosion control
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background Color	True
Out[4]=	Simulation Length	265
	Simulation Length	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

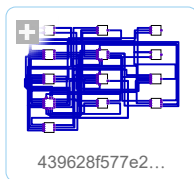
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

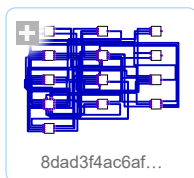
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

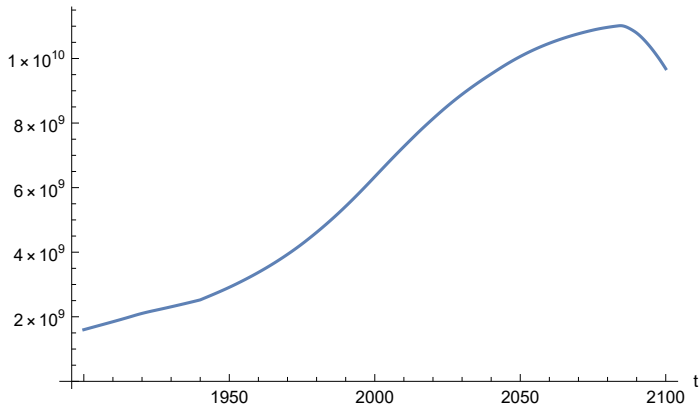
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W8dad3f4ac6af4b35b17ee78316499ff8
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

In[22]:= **SystemModelPlot**[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]

Out[22]=



Find max and min of population values.

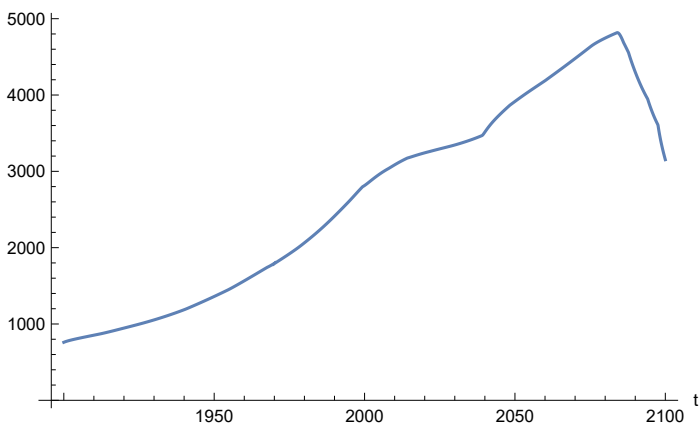
In[23]:= **MinAndMax**[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]

Maximum is 1.10166×10^{10}

Minimum is 1.6×10^9

In[24]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

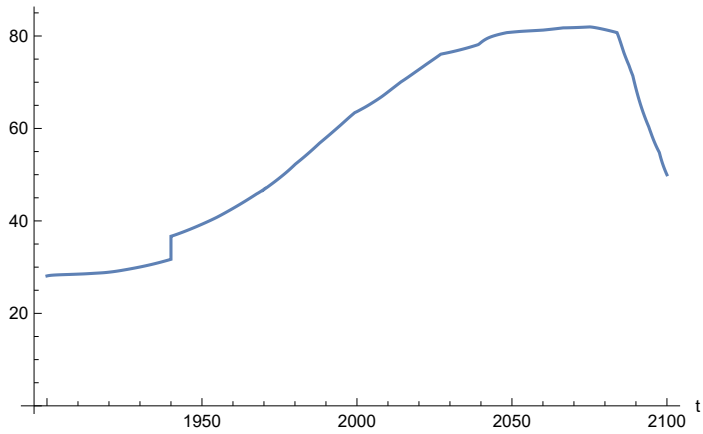
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[25]=

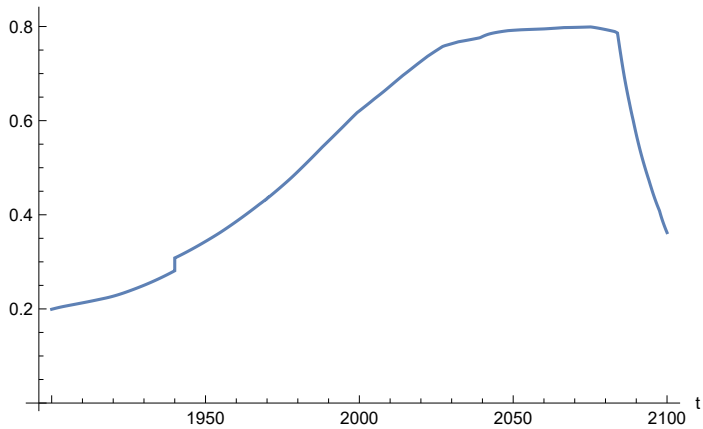


In[26]:=

Plot human welfare index.

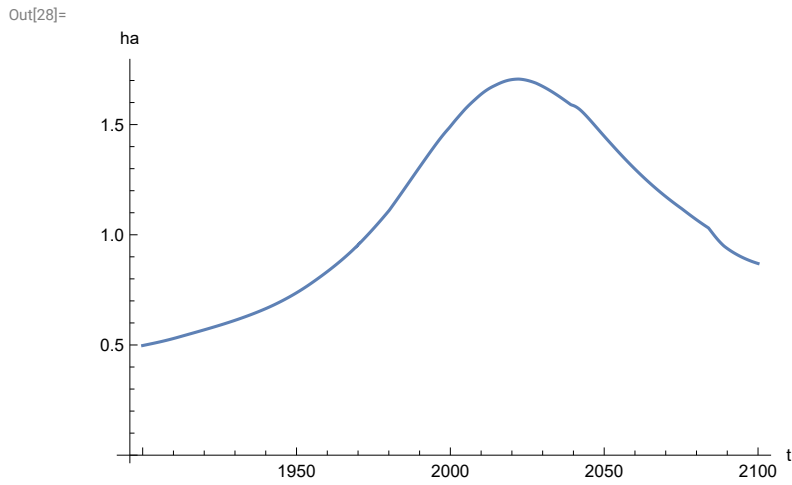
```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

Out[27]=



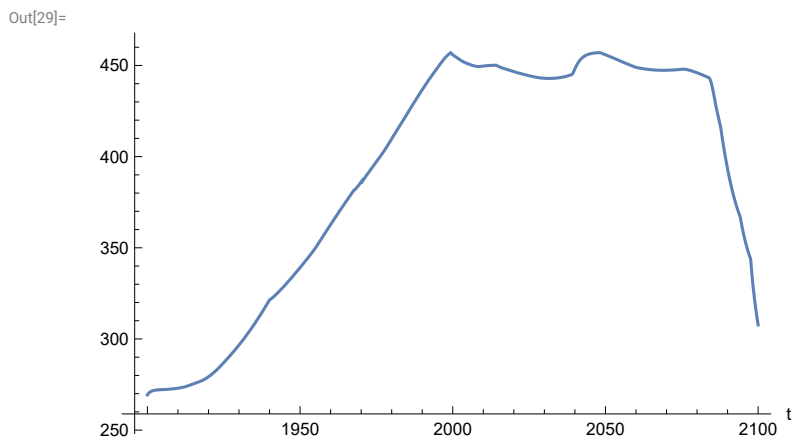
Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

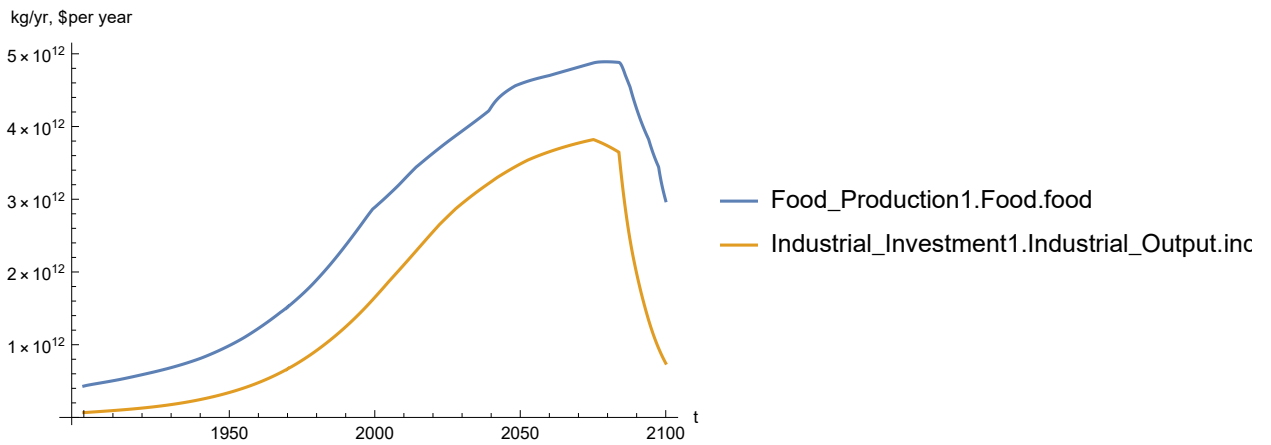
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

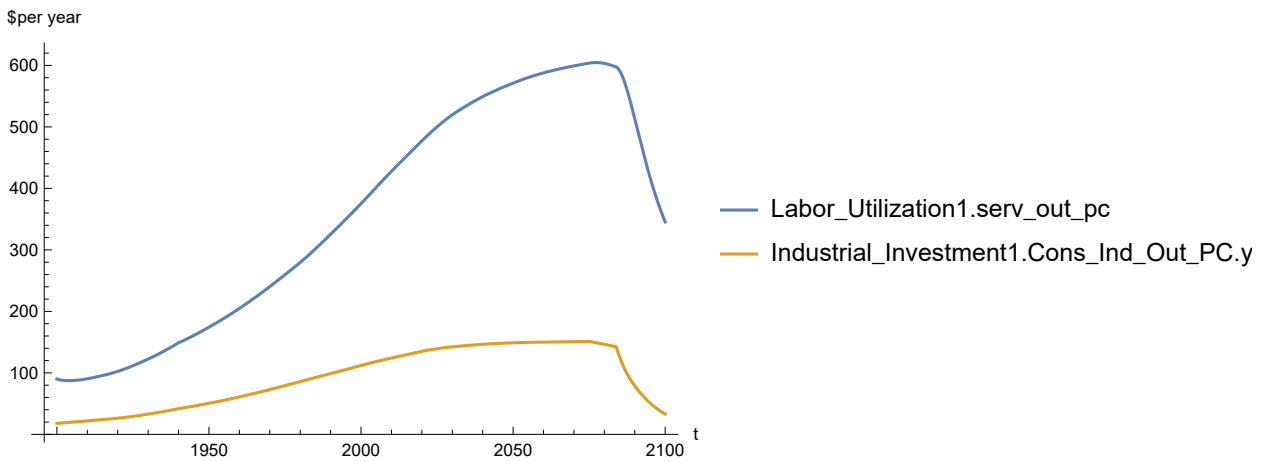
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim, {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

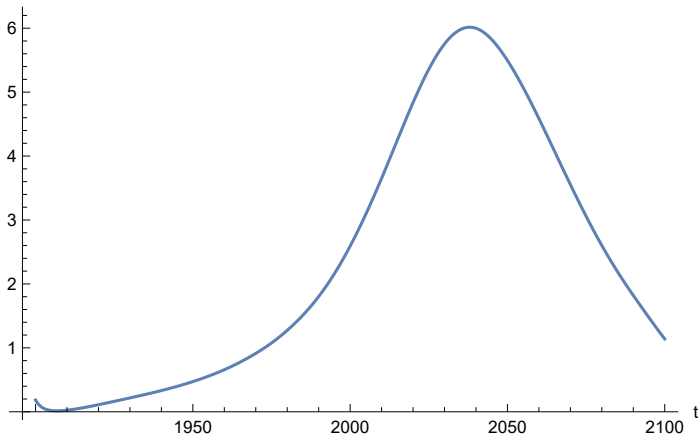
Maximum is 604.631

Minimum is 87.4451

Plot persistent pollution index.

In[33]:= **SystemModelPlot**[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]

Out[33]=



Find max and min of y values.

In[34]:= **MinAndMax**[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]

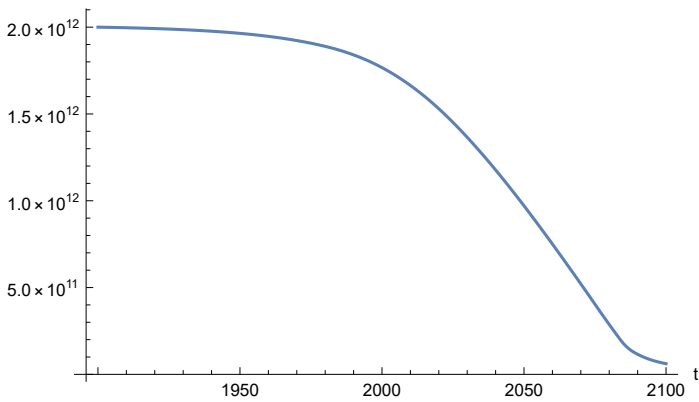
Maximum is 6.01532

Minimum is 0.0150765

Plot non-renewable resources remaining.

In[35]:= **SystemModelPlot**[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]

Out[35]=

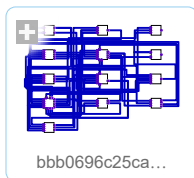


APPENDIX 57. LE/1.001, t_policy_year = 2025. Baseline Scenario 5, Experiment 57.

Set `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals` to LE/1.001. Note: this particular divisor does not change the two-significant-figure default `_Serv_2.y_vals`

```
In[36]:= strsim = SystemModel [  
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →  
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0} }|>]
```

Out[36]=



Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals`.

```
In[37]:= SystemModel [strsim] [  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel [strsim] [  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel [strsim] [  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel [strsim] [  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel [strsim] [  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel [strsim] [  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

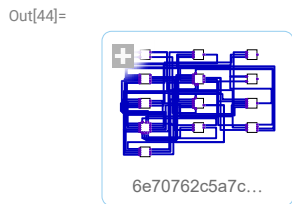
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```



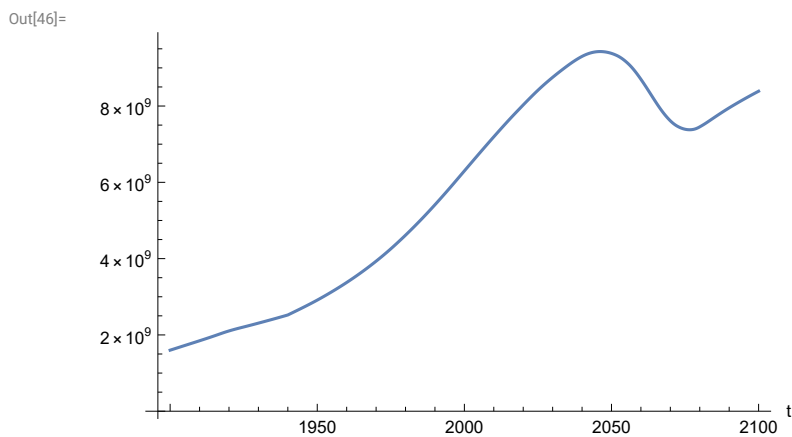
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W6e70762c5a7c4afd8e61bb19a2cc8523
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

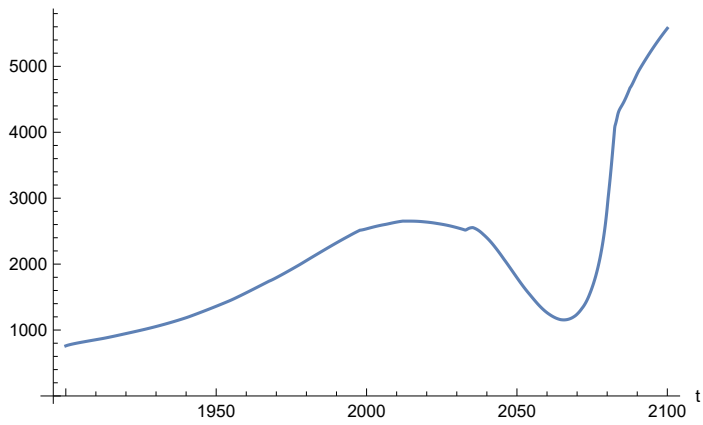
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 9.4281×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

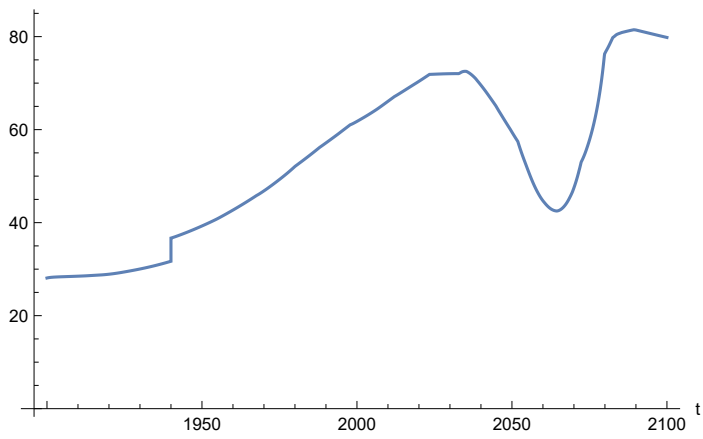
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

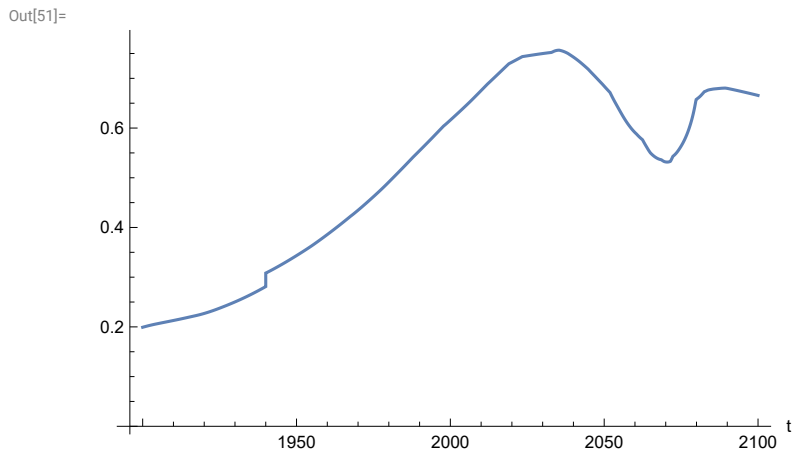
Out[49]=



In[50]:=

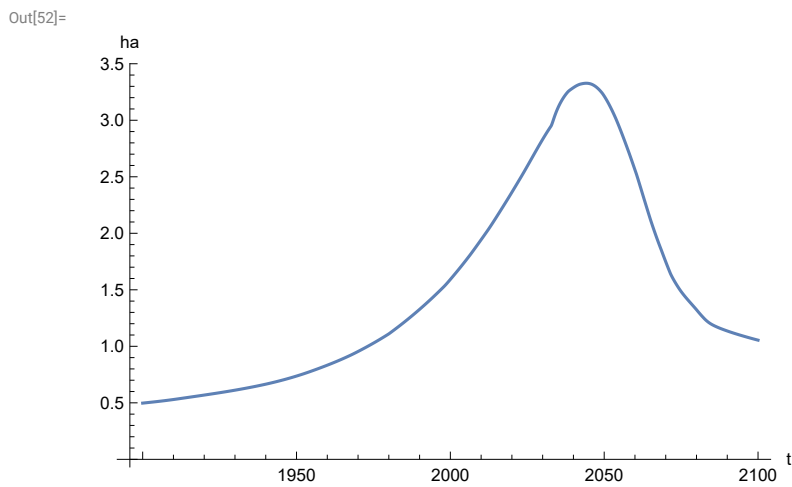
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

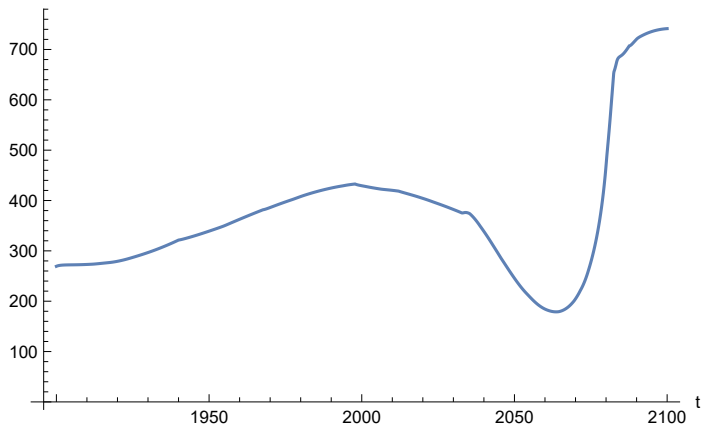
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

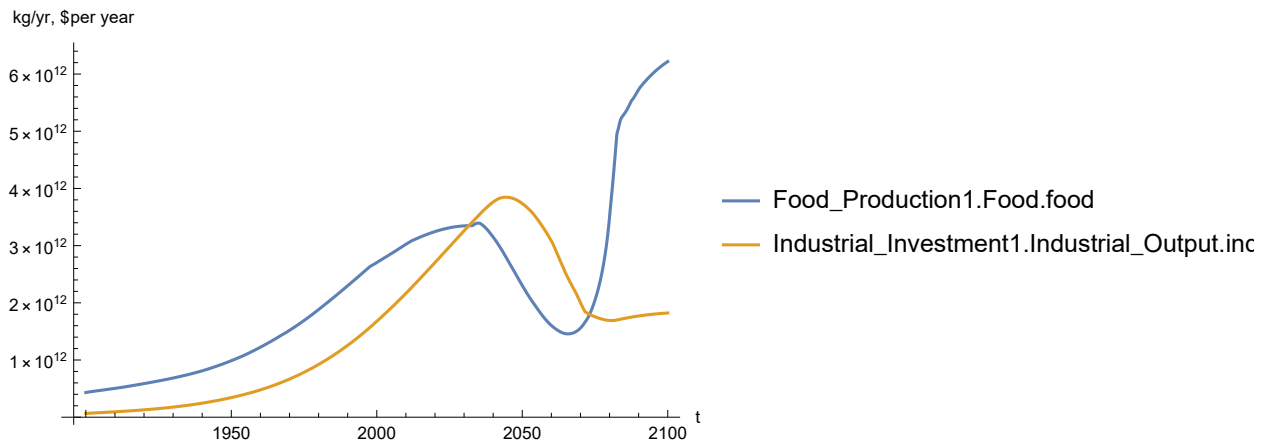
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

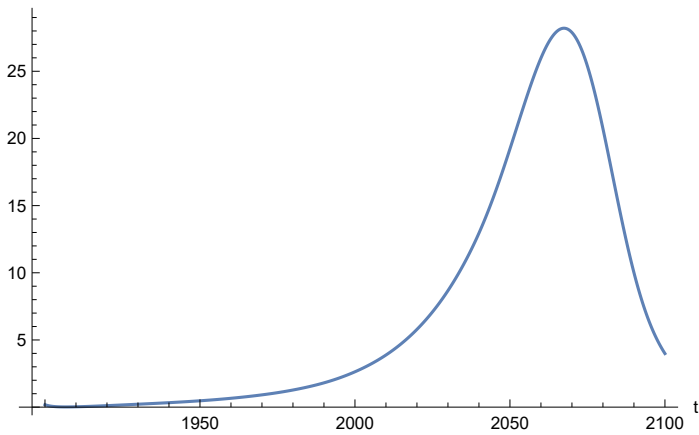


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 709.944
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



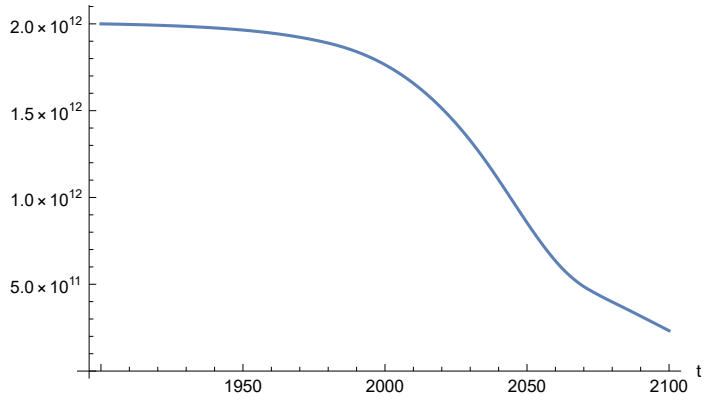
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 28.2044
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

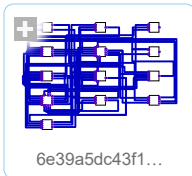


APPENDIX 58. LE/1.01, t_policy_year = 1970. Baseline Scenario 5, Experiment 58.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

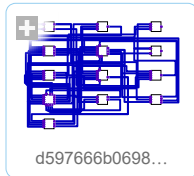
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}}>]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

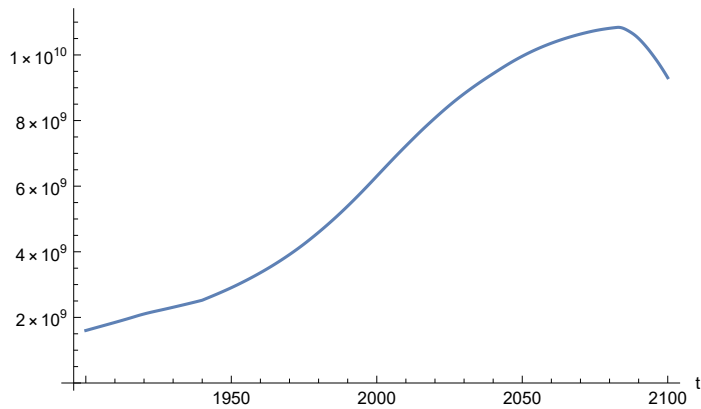
```
Out[69]=
```

```
SystemModelSimulationData [
   Model: Wd597666b069843249b3dc83b7c2a1bd4
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

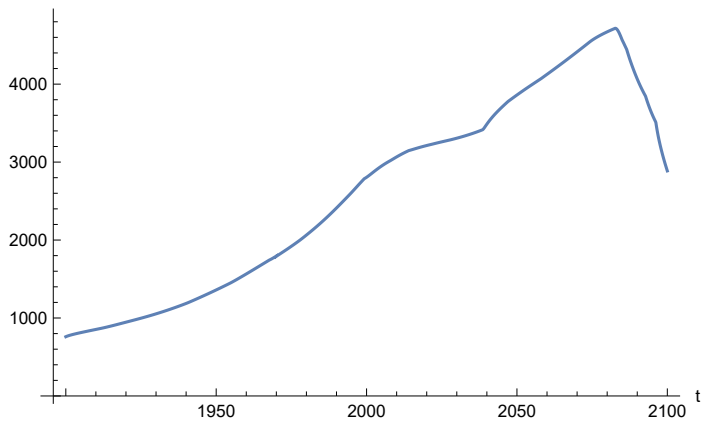
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $1.08417 \times 10^{10}$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

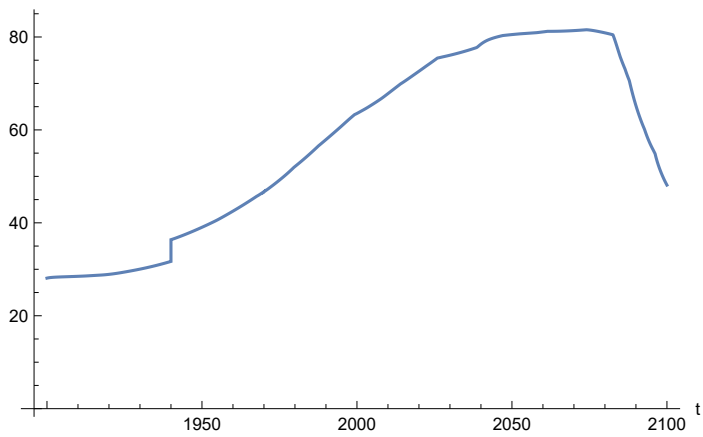
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

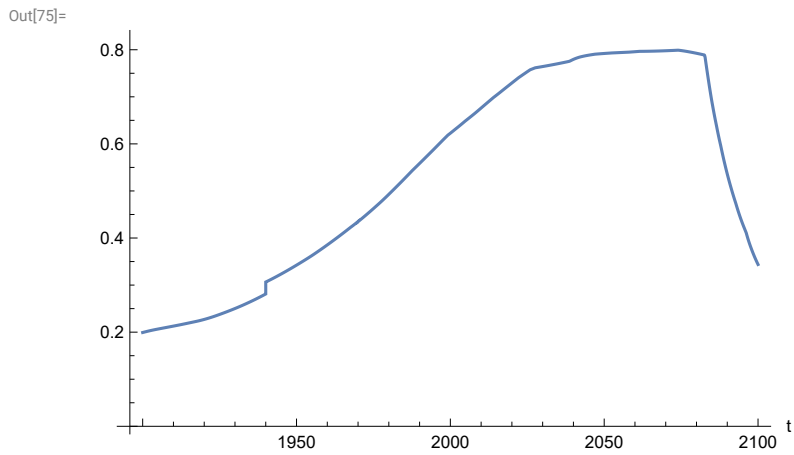
Out[73]=



In[74]:=

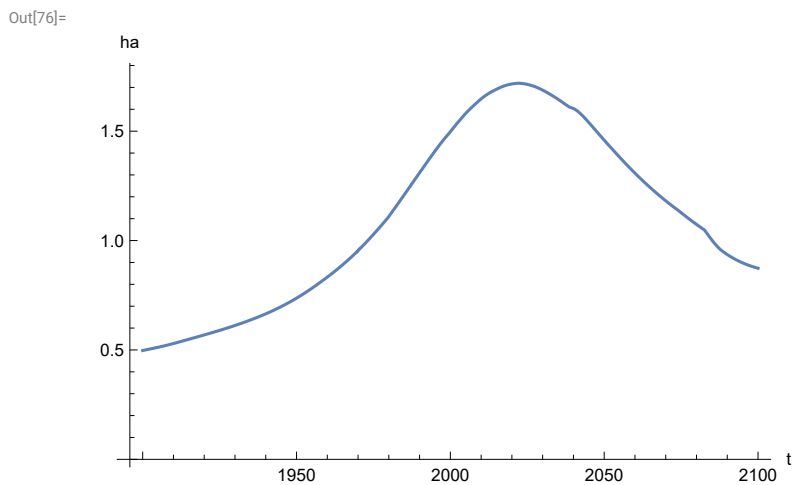
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



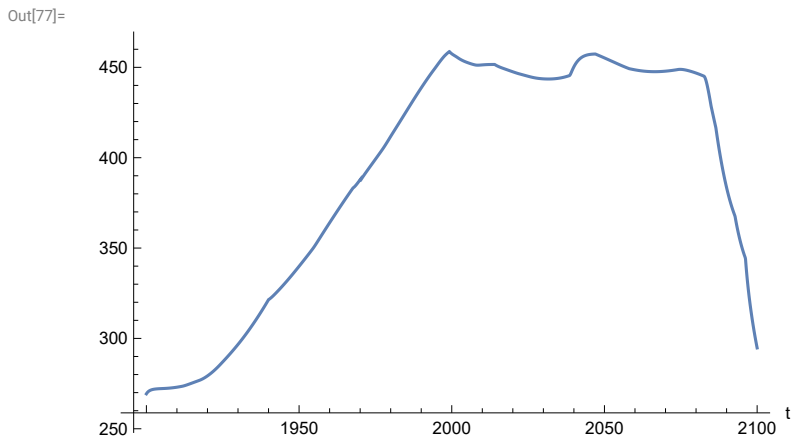
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



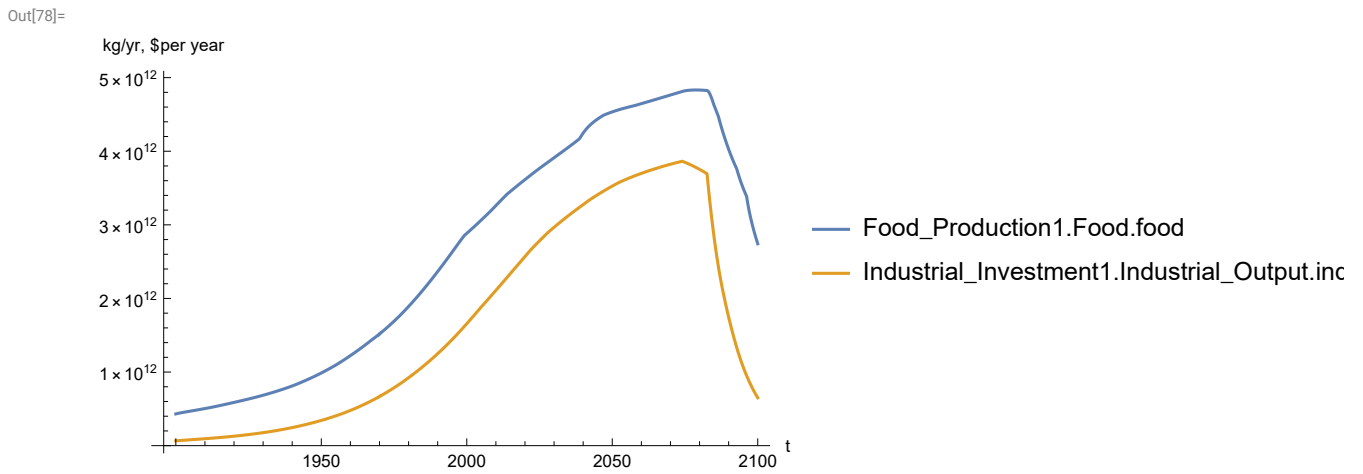
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

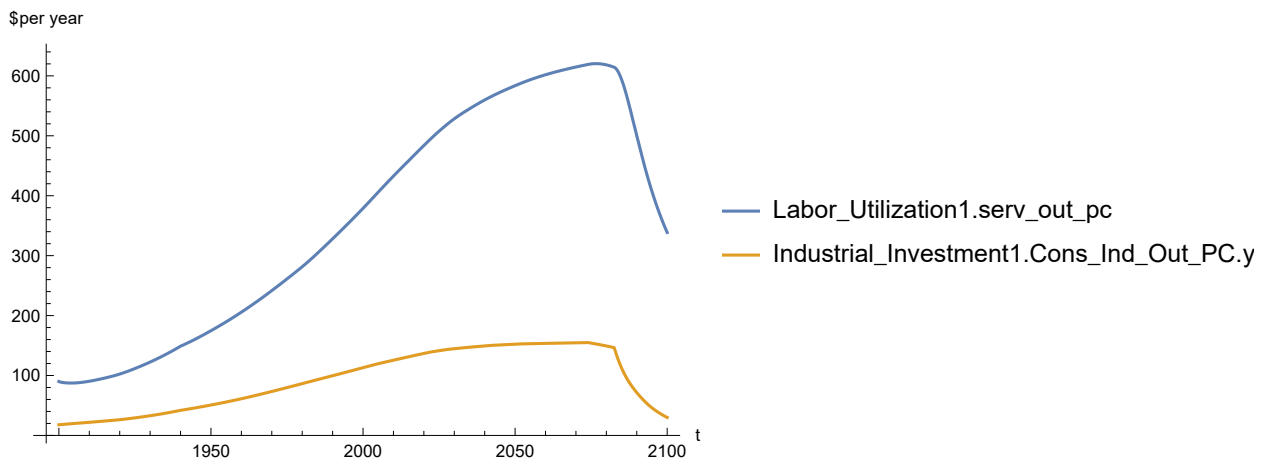
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



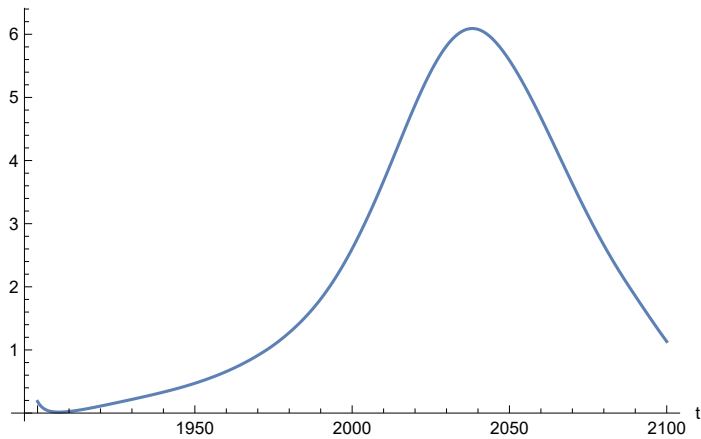
Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 620.386
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



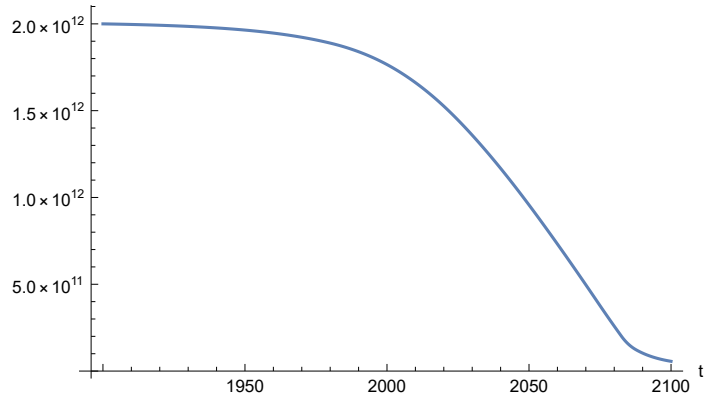
Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 6.09145
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

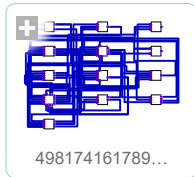
Out[83]=



APPENDIX 59. Baseline Scenario 5, Experiment 59. $LE = LE/1.01$, $t_policy_year = 2025$.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

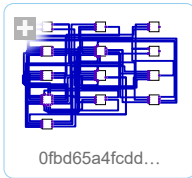
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



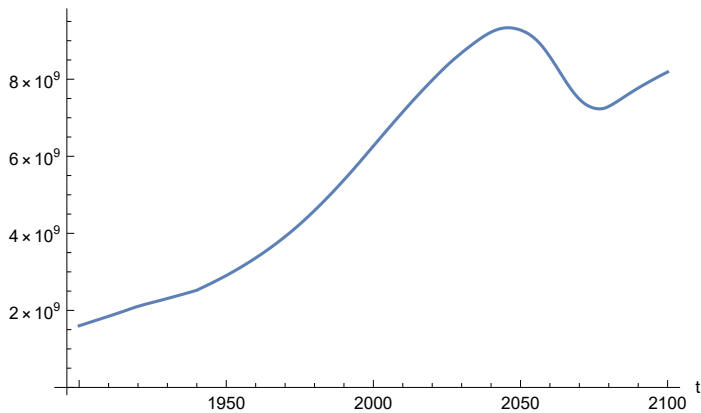
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

```
SystemModelSimulationData [ Model: W0fbd65a4fodd44e29396a5f70330d4af
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

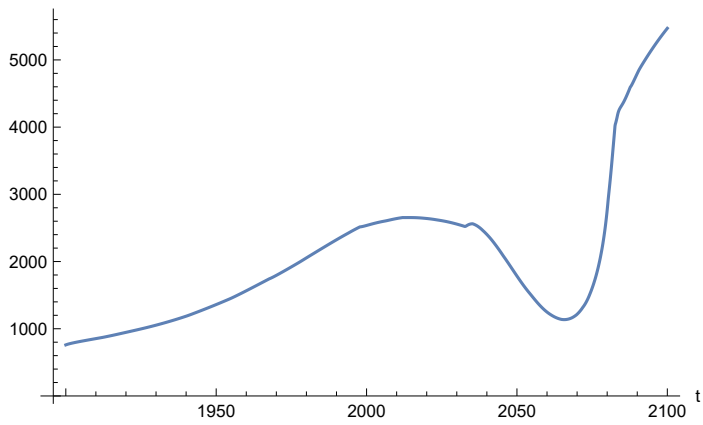


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.33585 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

In[96]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

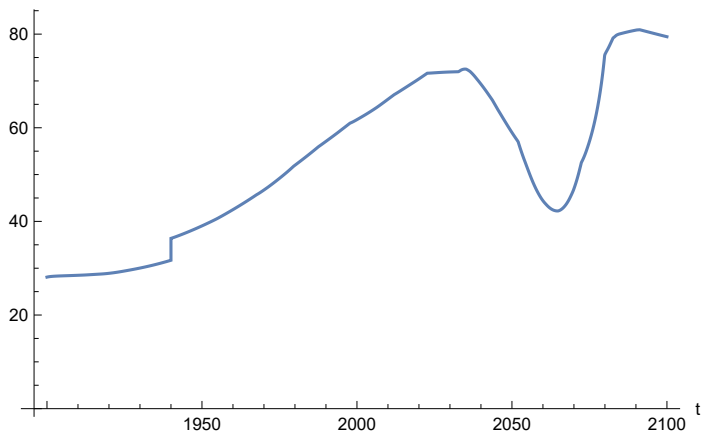
Out[96]=



Plot life expectancy, years.

In[97]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

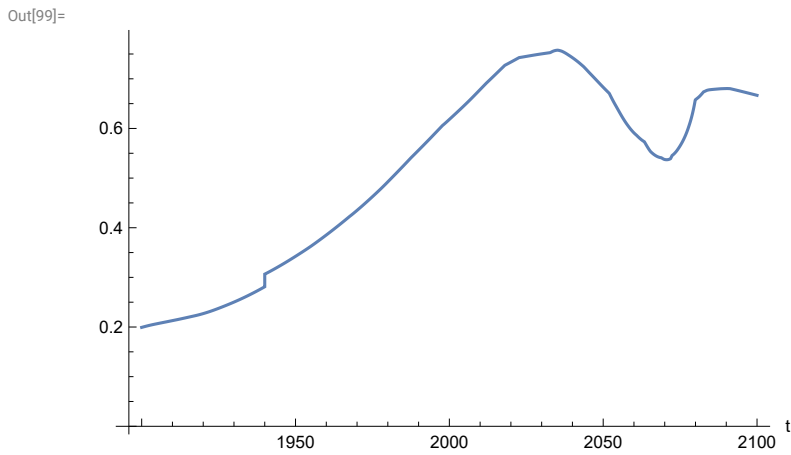
Out[97]=



In[98]:=

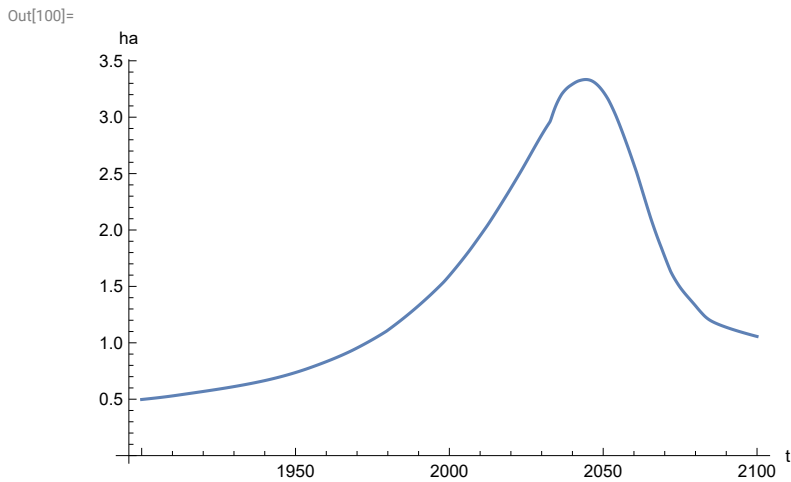
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

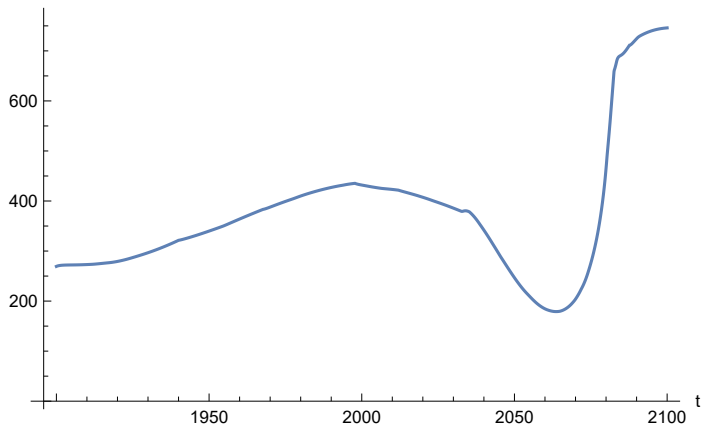


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

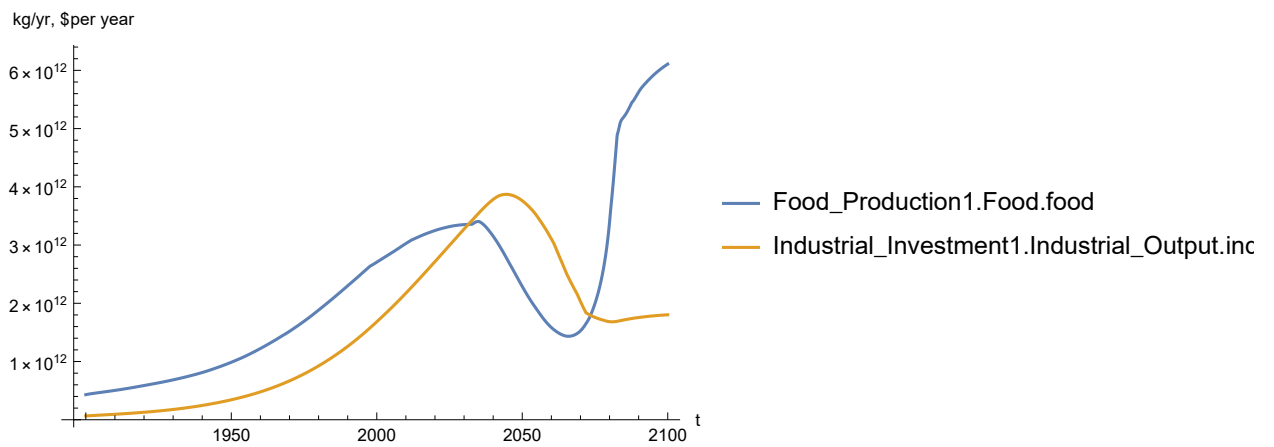


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

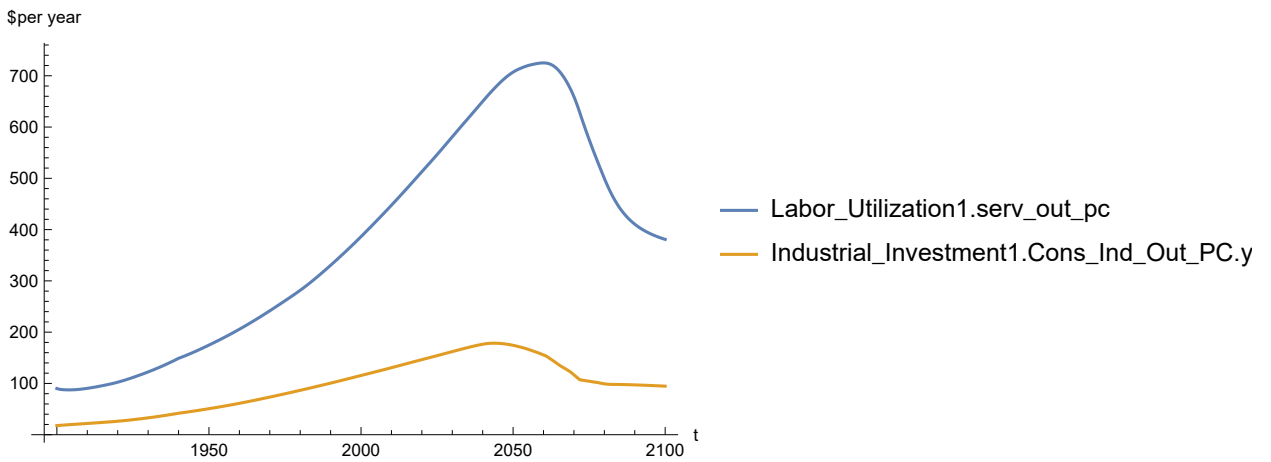


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]=



Find max and min of y values.

In[104]:=

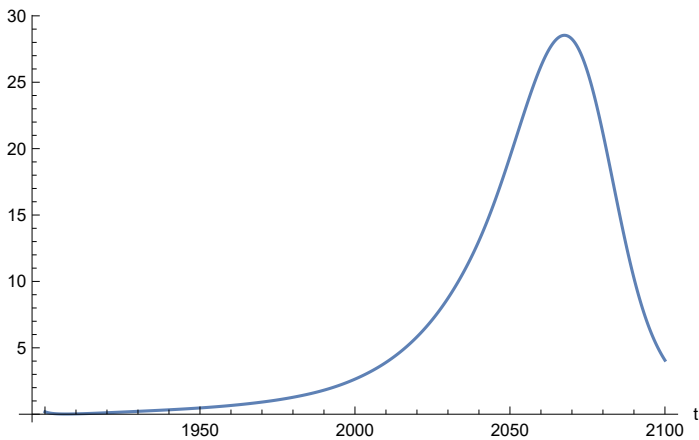
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 725.06
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 28.5347

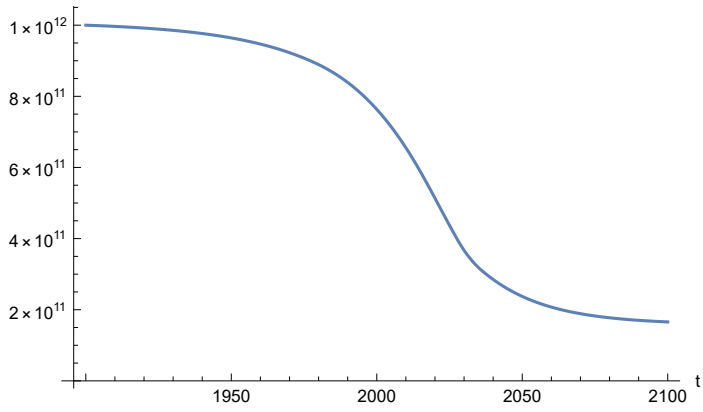
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 60. BENCHMARK SCENARIO 5, Experiment 60. $LE = LE/1.03$, $t_{policy_year} = 1970$.
Last modified: 22 July 2022/1215 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

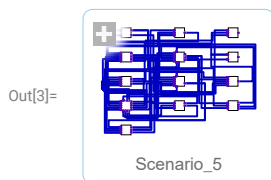
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

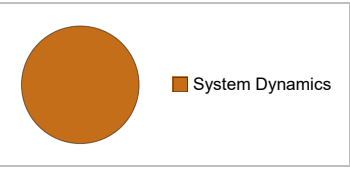
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 5.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_5"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_5
	Description	More accessible non-recoverable natural resources, pollution control, land yield enhancement, and erosion control
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background Color	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

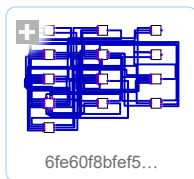
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

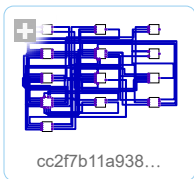
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set t_policy_year to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}}>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

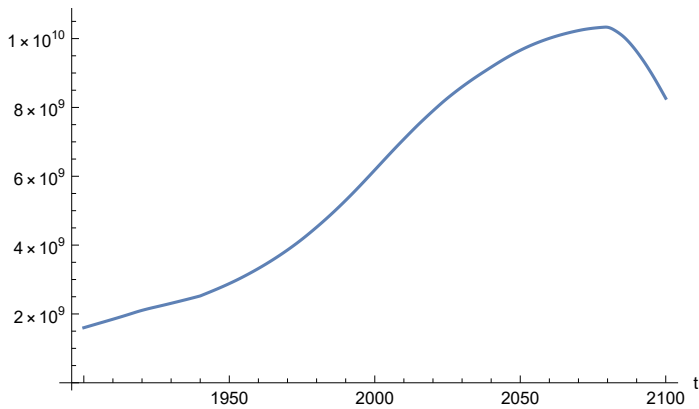
```
Out[21]=
```

```
SystemModelSimulationData [  Model: Wcc2f7b11a938415683db3f962d1d83d1
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

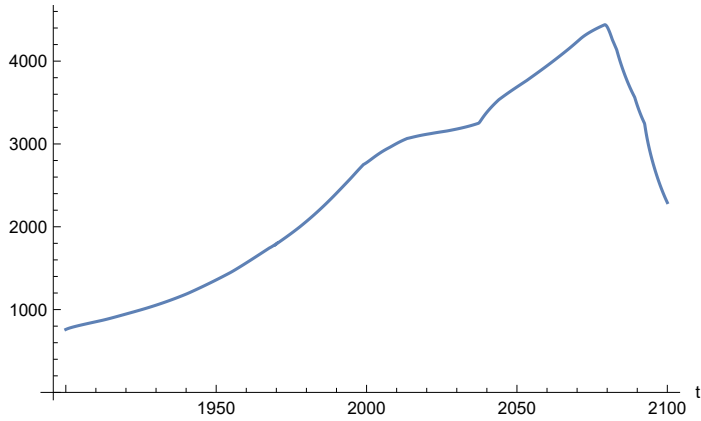
```
Out[22]=
```



Find max and min of population values.

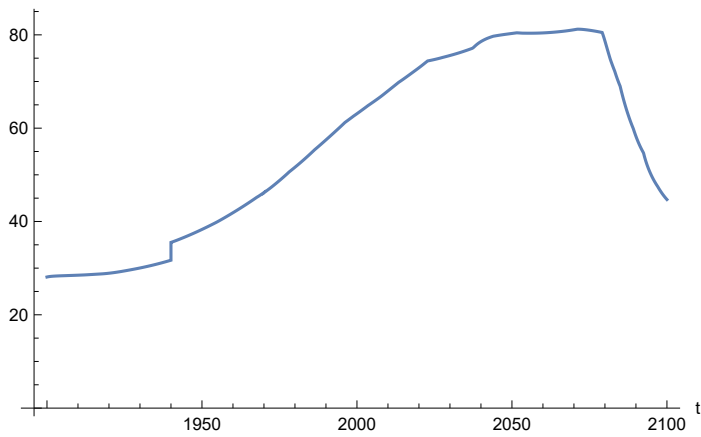
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $1.03335 \times 10^{10}$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

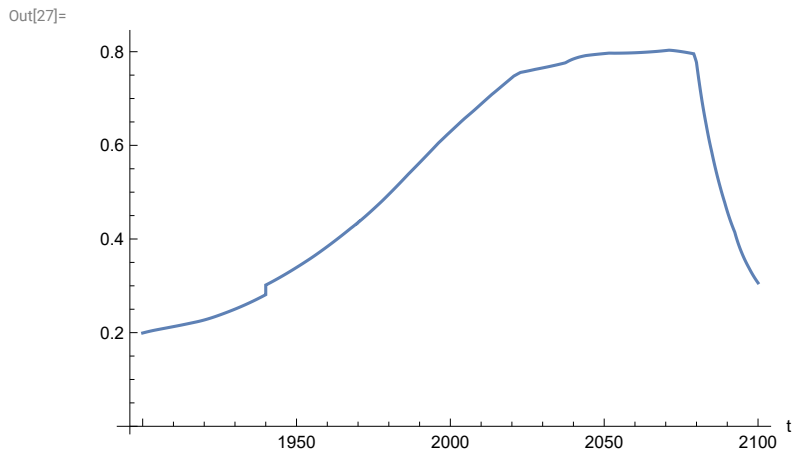
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```



```
In[26]:=
```

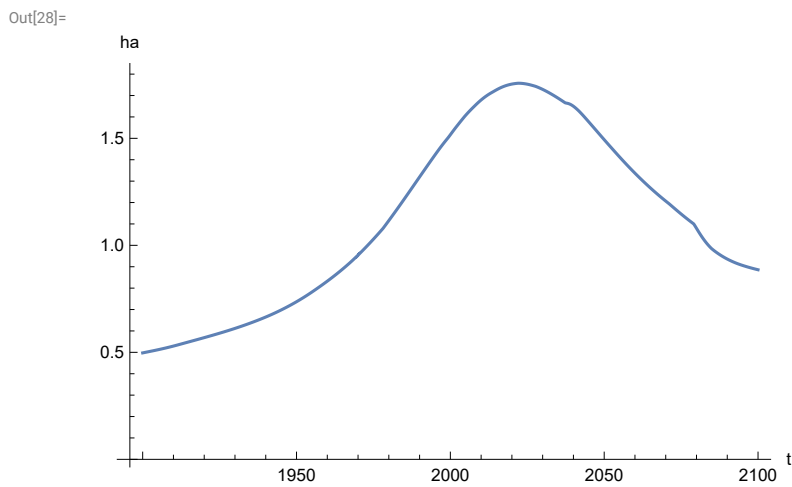
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,  
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

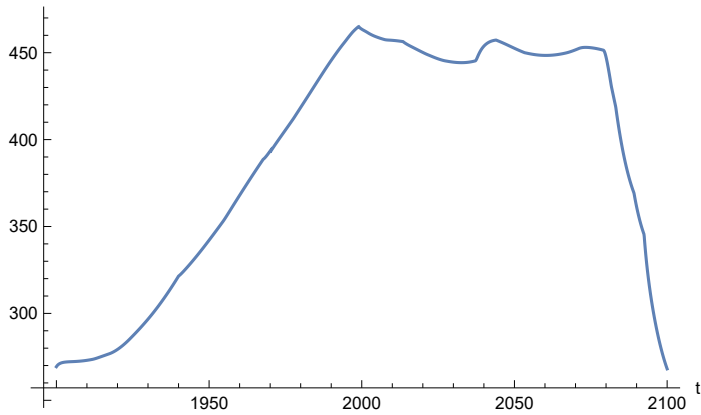
```
In[28]:= SystemModelPlot[basesim,  
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
  _footprint"}]
```



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

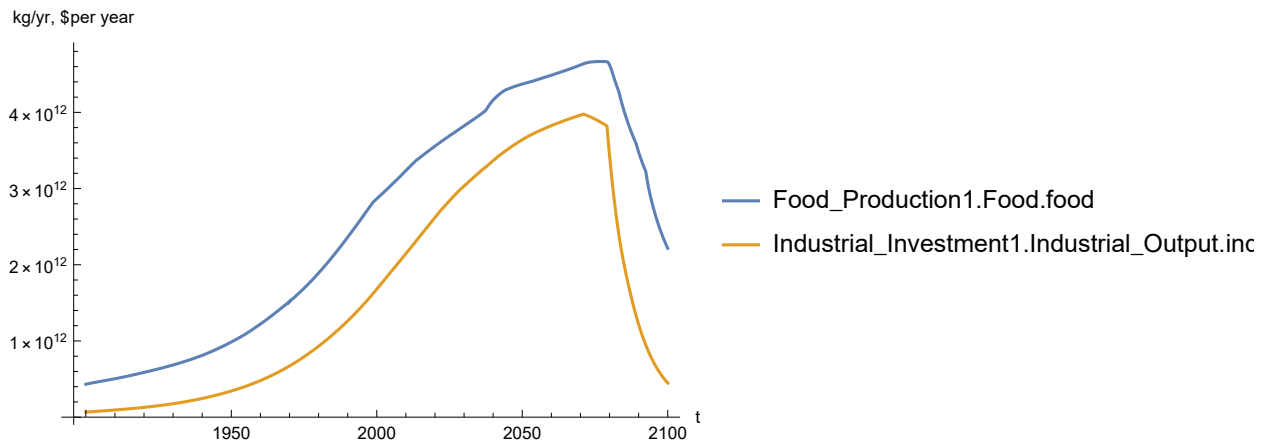
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

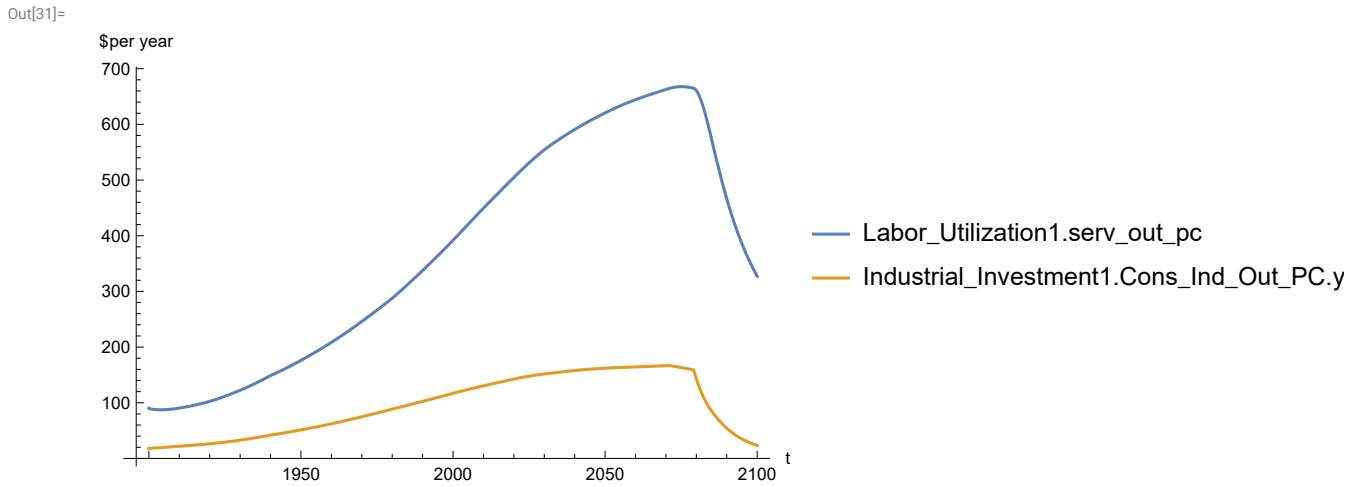
In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

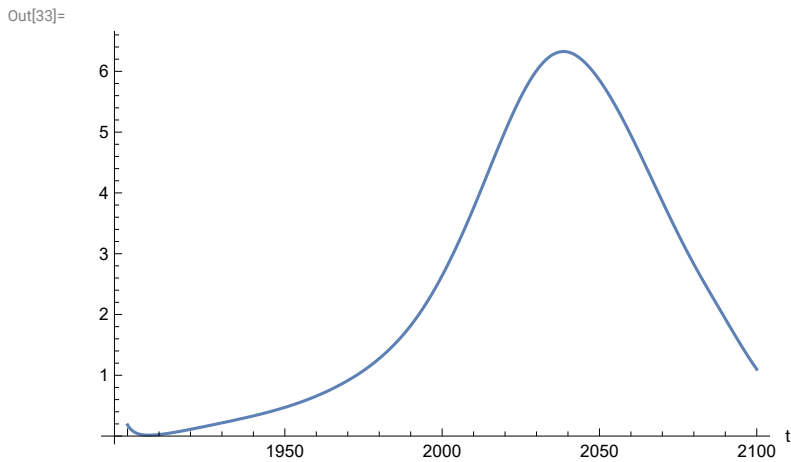


Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 667.752
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



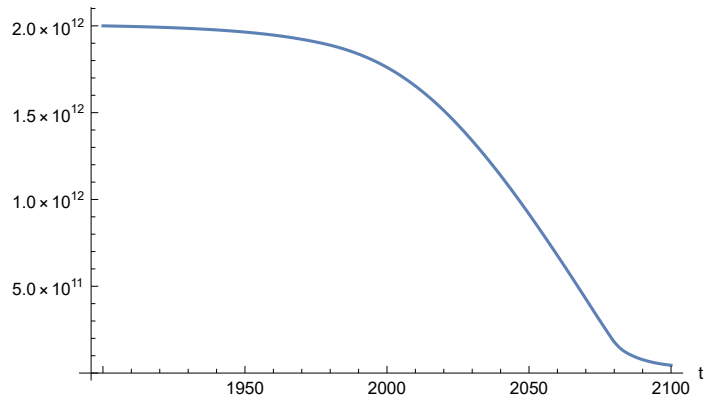
Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 6.32602
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

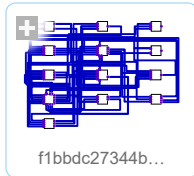


APPENDIX 61. LE/1.03, t_policy_year = 2025. Baseline Scenario 5, Experiment 61.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

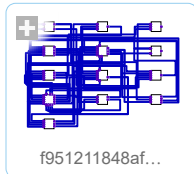
```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```


```
Out[44]=
```



Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

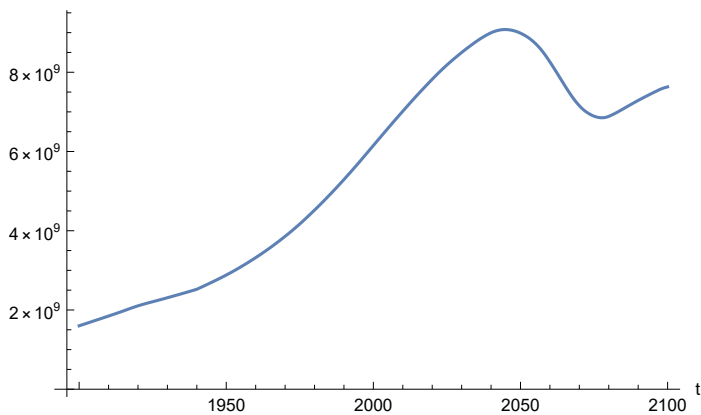
```
Out[45]=
```

```
SystemModelSimulationData [ {  Model: Wf951211848af4cefb7446937ecfd7ed8
  Time: 1.90 × 103 to 2.10 × 103 } ]
```

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[46]=
```



Find max and min of population values.

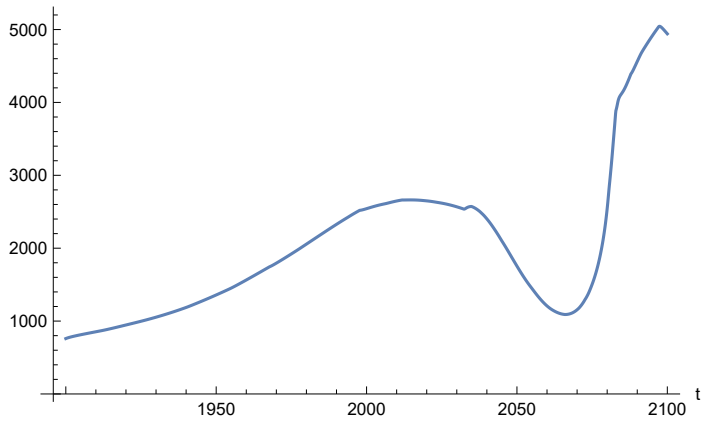
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.07784 × 109
```

```
Minimum is 1.6 × 109
```

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

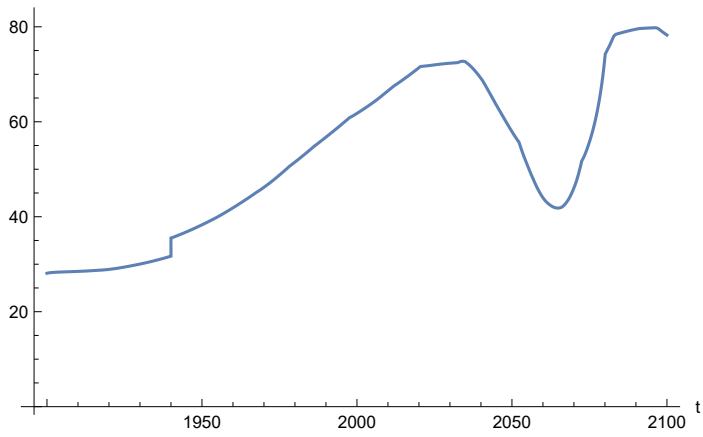
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

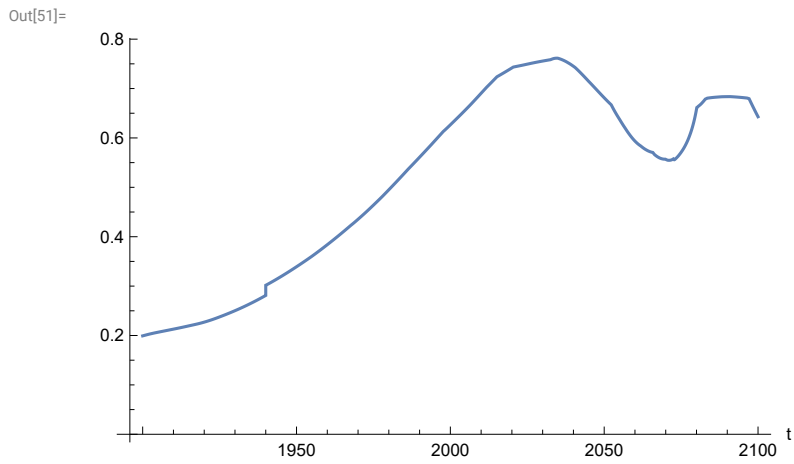
Out[49]=



In[50]:=

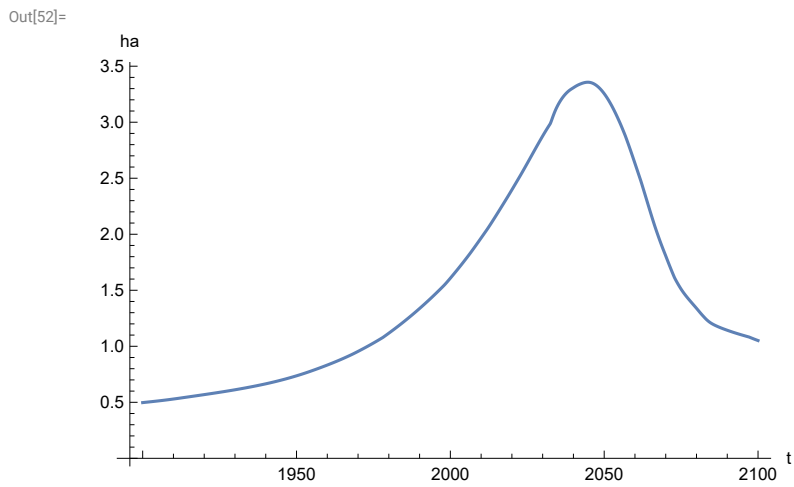
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

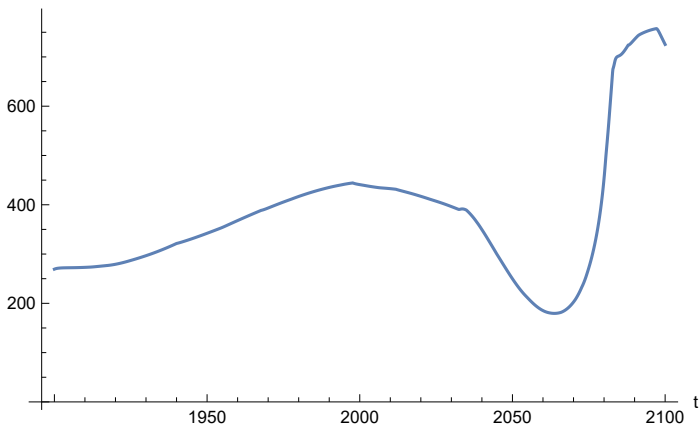
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

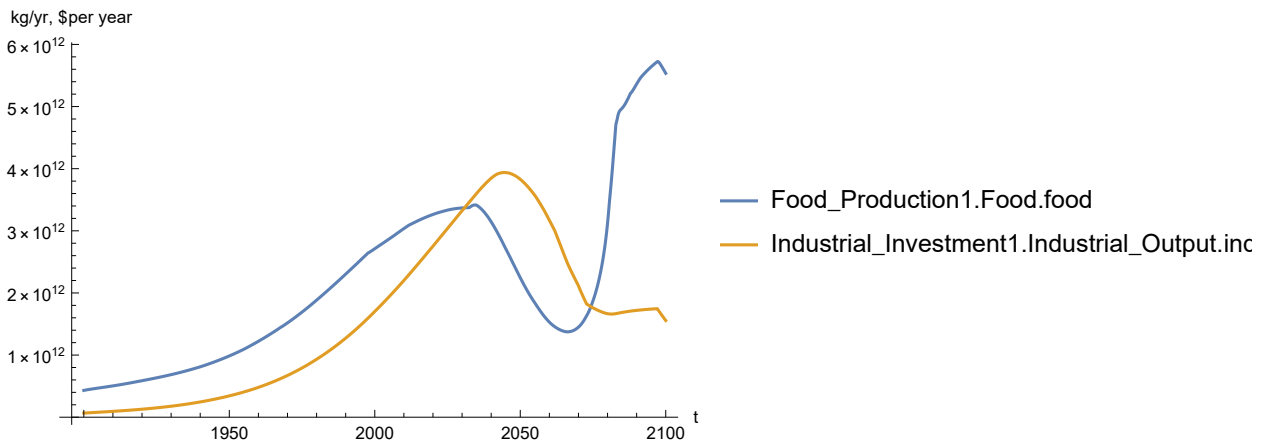
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

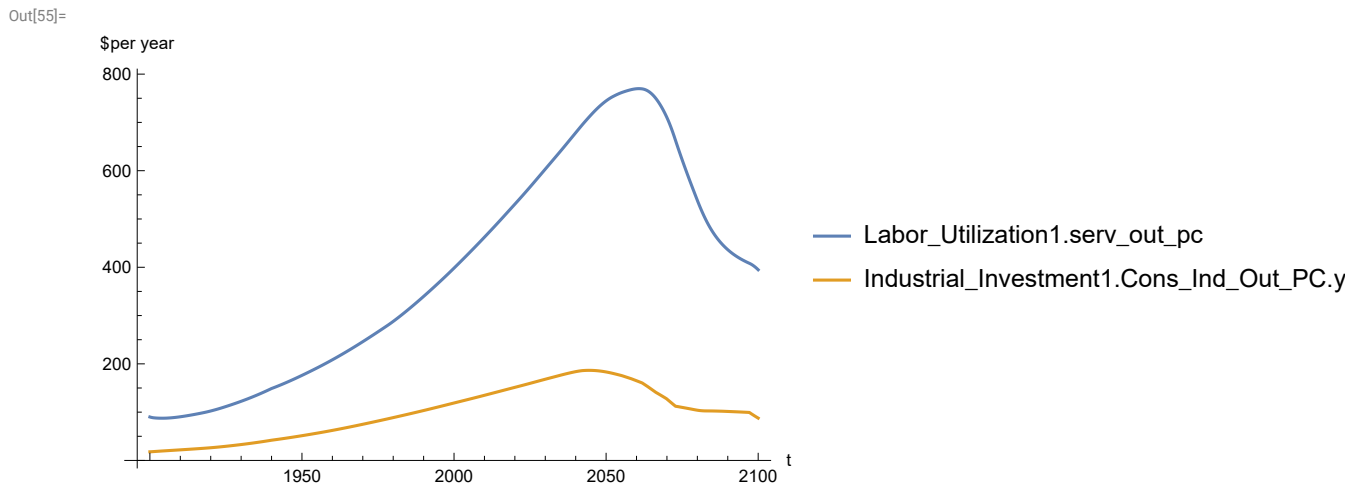
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

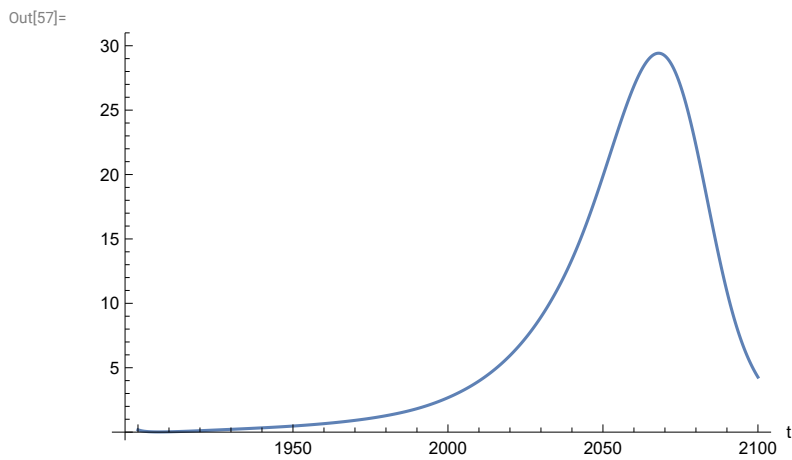


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 769.916
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



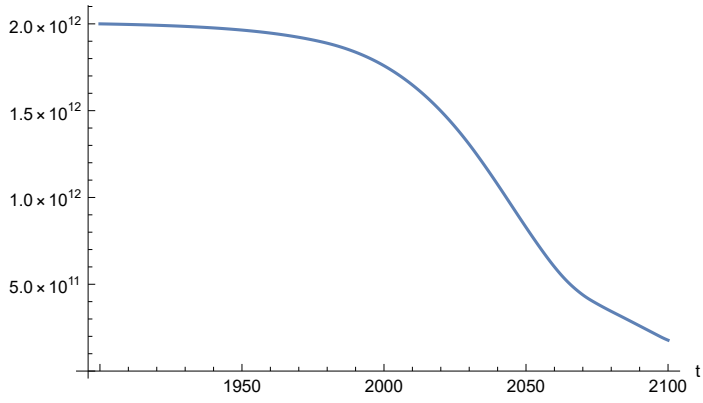
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 29.4196
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

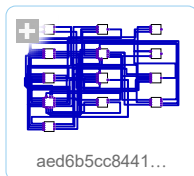


APPENDIX 62. LE/1.05, t_policy_year = 1970. Baseline Scenario 5, Experiment 62.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

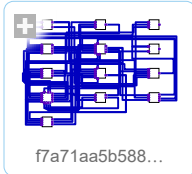
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```


```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

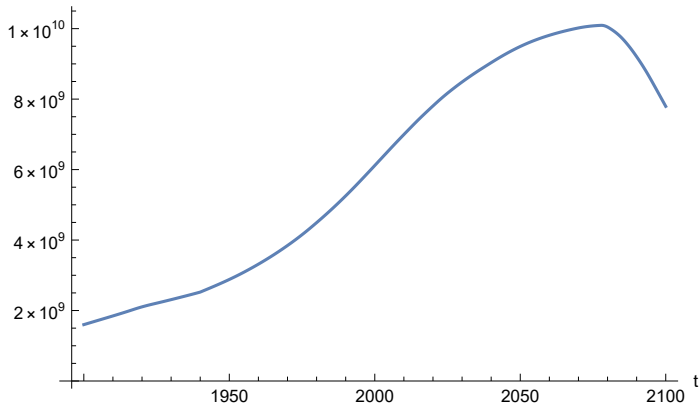
```
Out[69]=
```

```
SystemModelSimulationData [  Model: Wf7a71aa5b588430eab394637e3ecc423  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

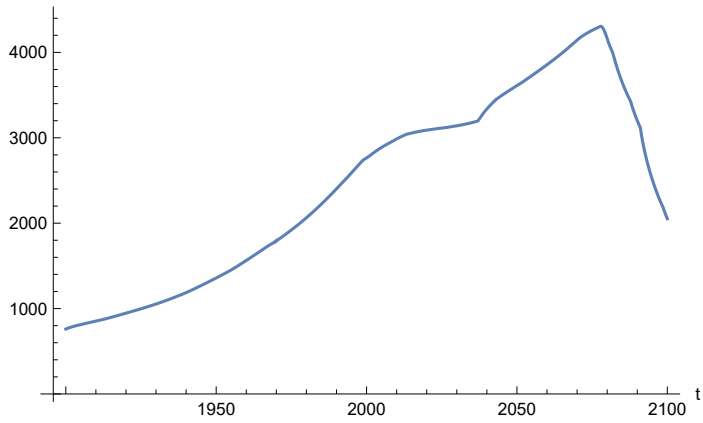
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $1.00939 \times 10^{10}$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

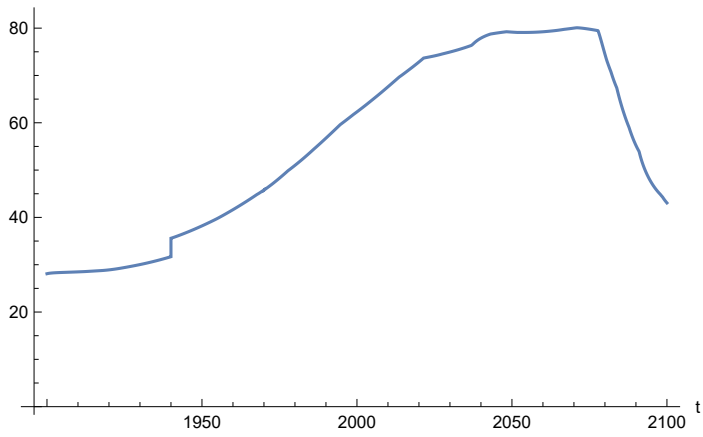
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

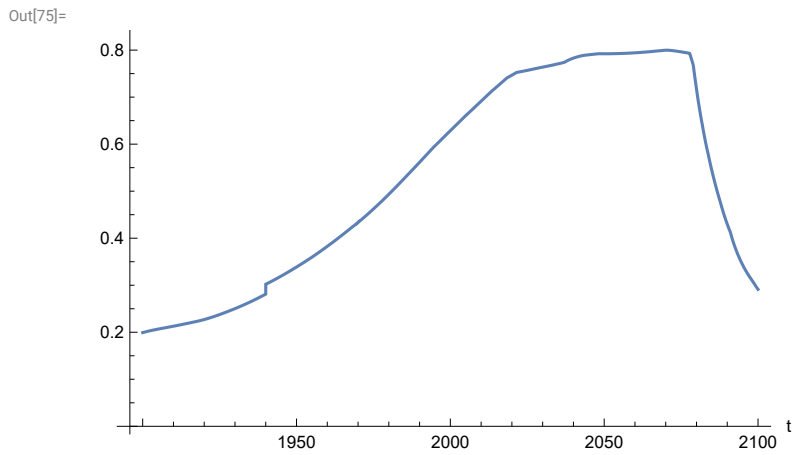
Out[73]=



In[74]:=

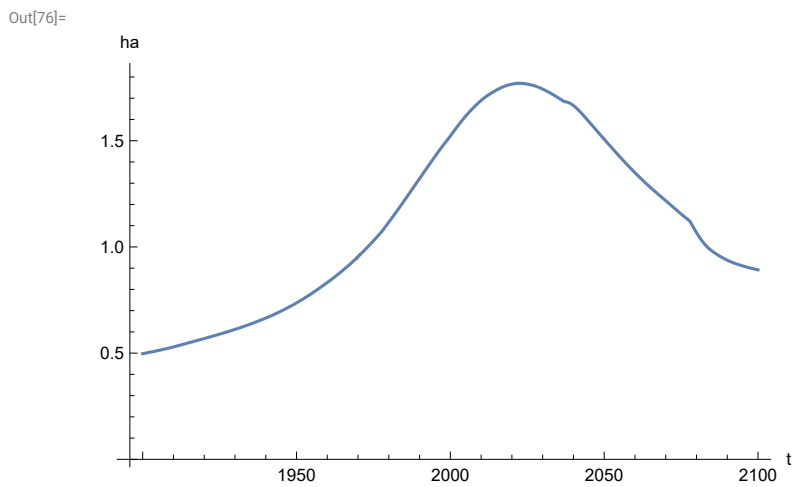
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

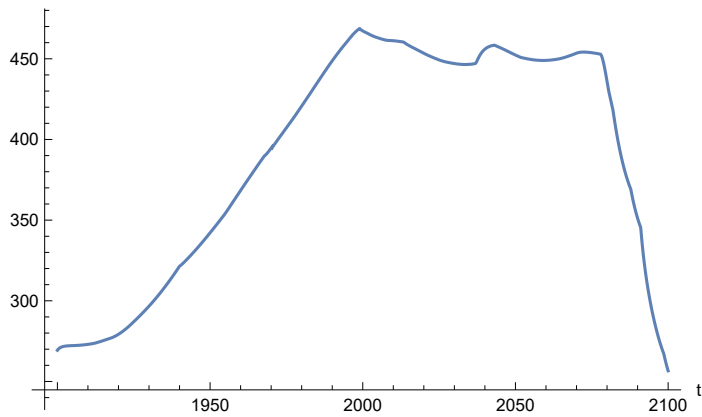
```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[77]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

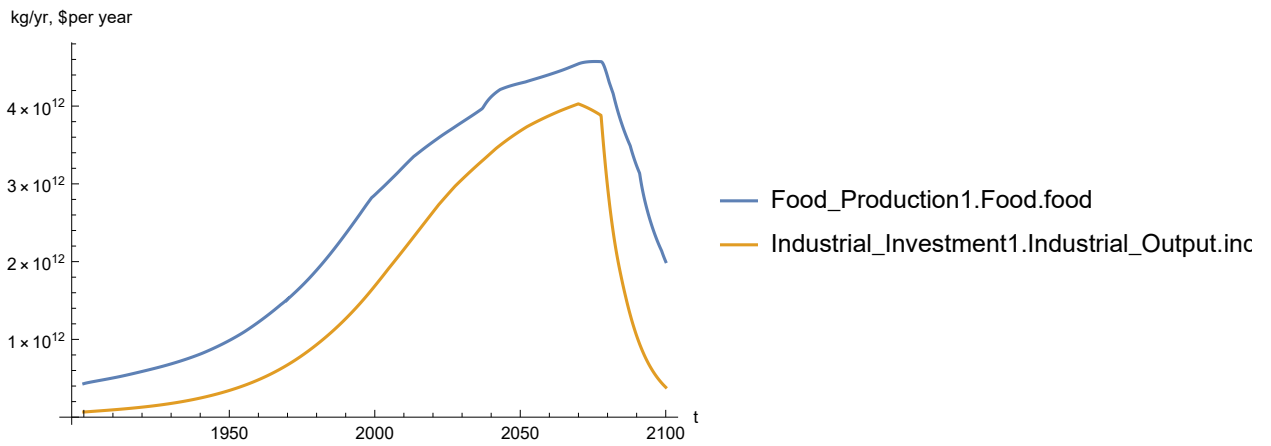
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[78]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

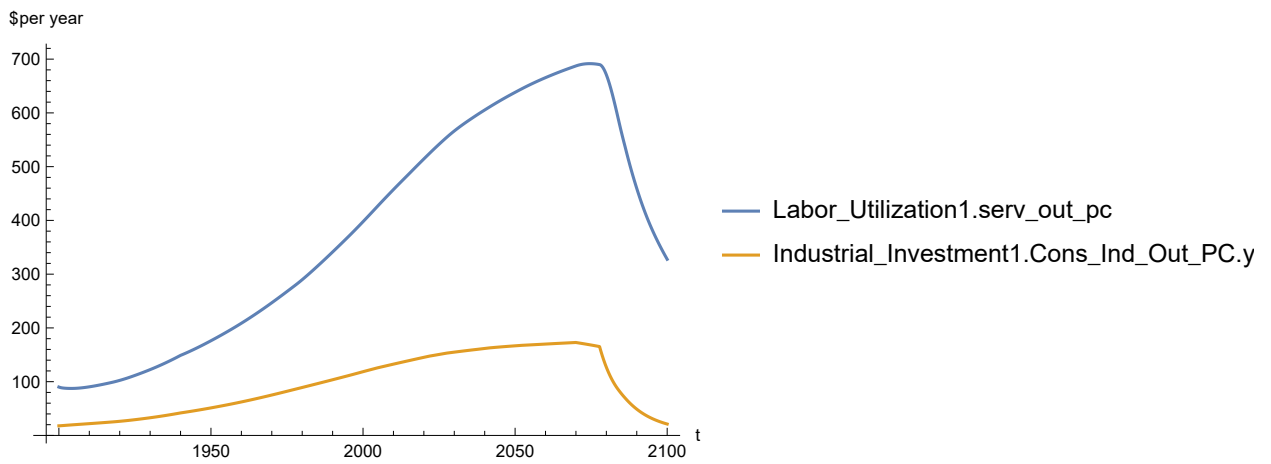
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



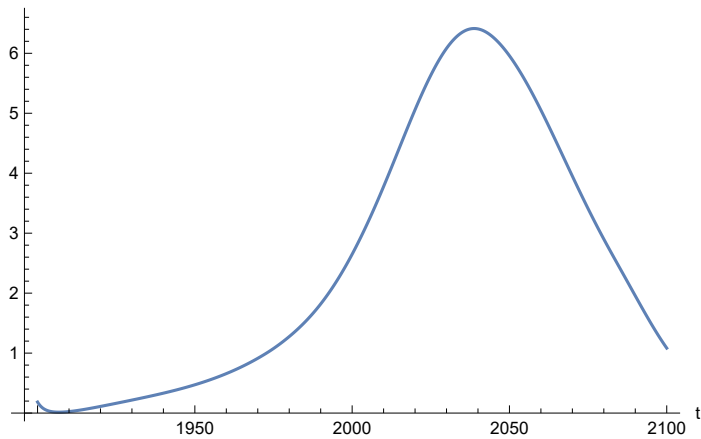
Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 691.604
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



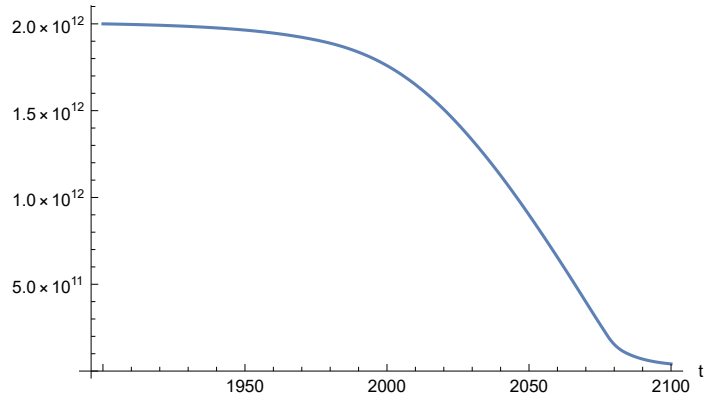
Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 6.41325
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

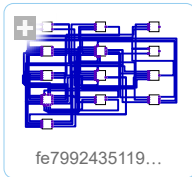
Out[83]=



APPENDIX 63. Baseline Scenario 5, Experiment 63. LE = LE/1.05, t_policity_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

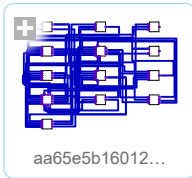
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



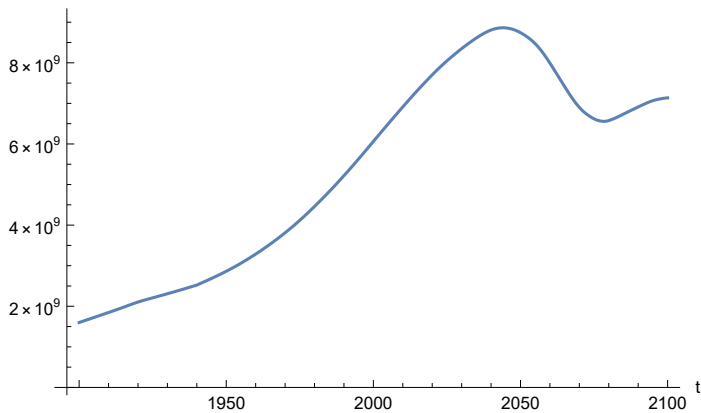
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

```
SystemModelSimulationData [ Model: Waa65e5b1601246e88188973864f110c9
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

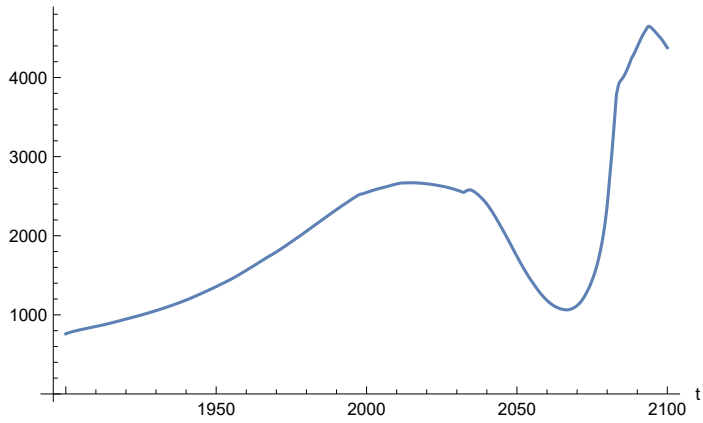


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.8632 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

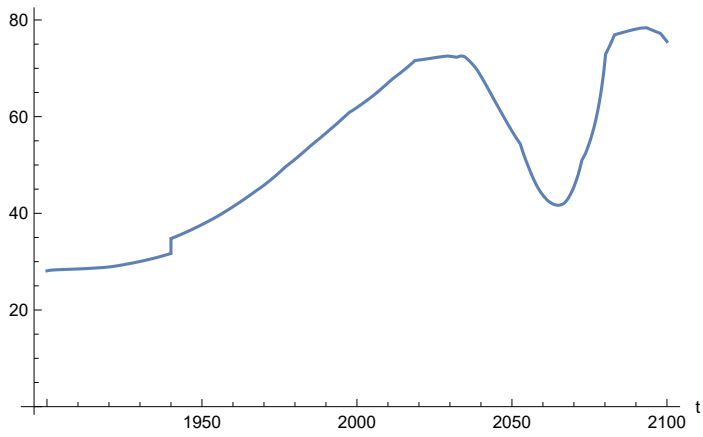
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

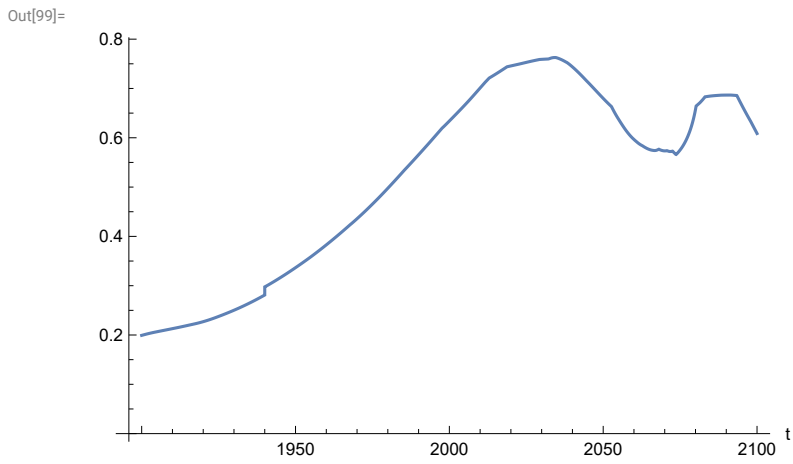
Out[97]=



In[98]:=

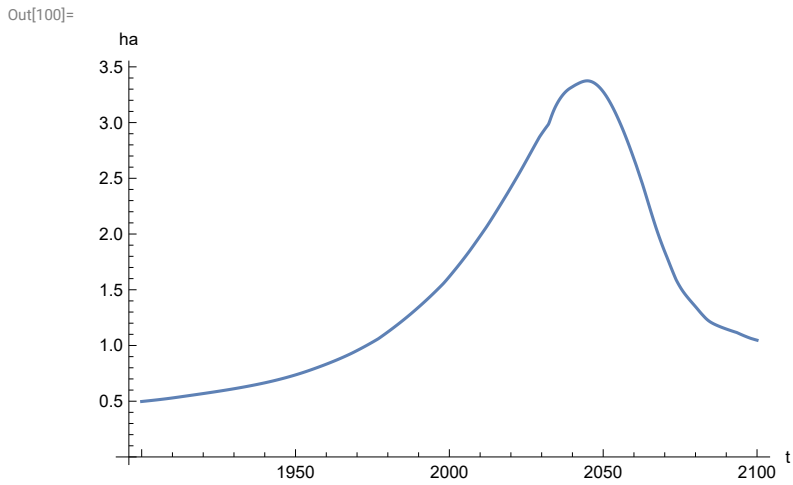
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

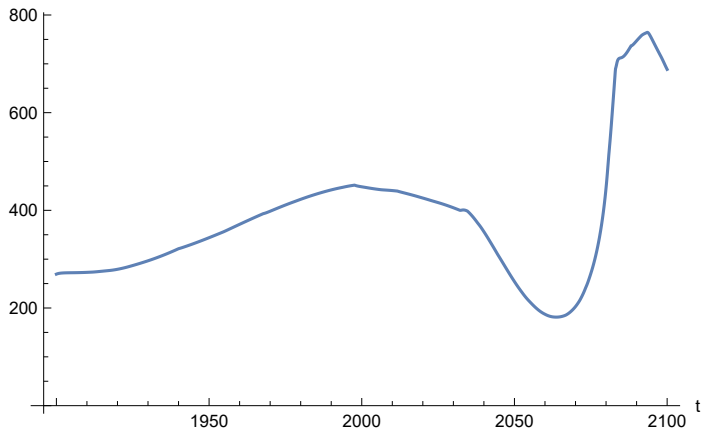


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

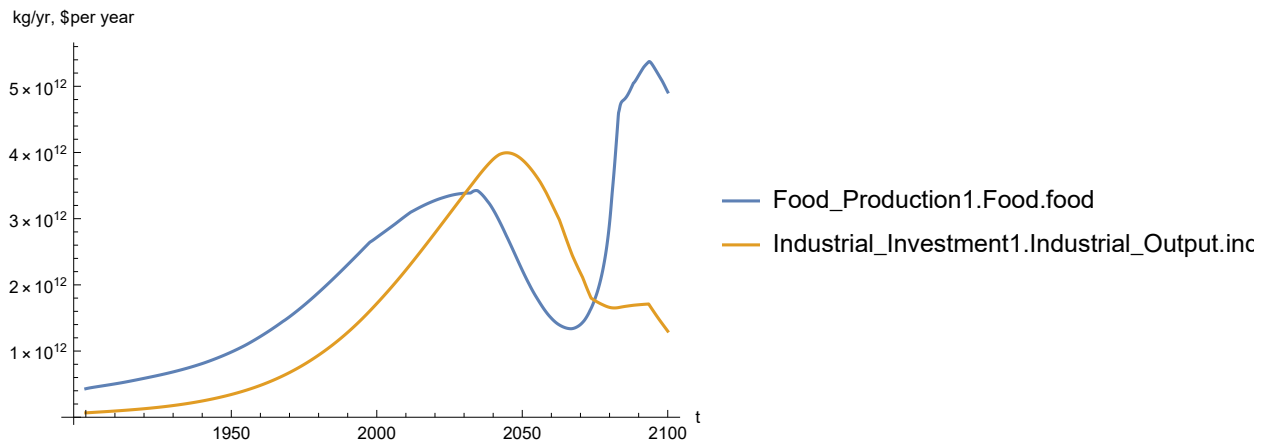


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

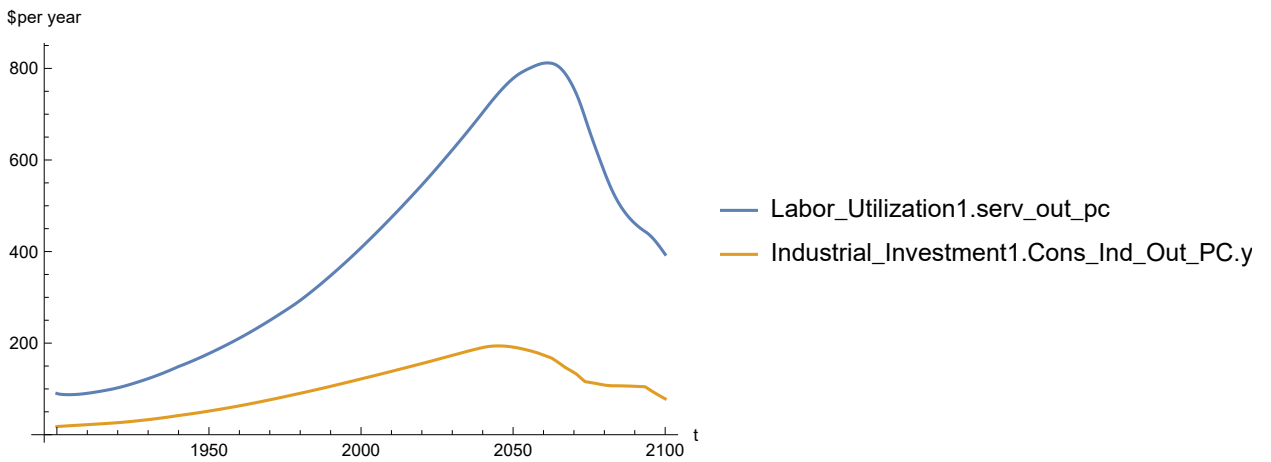


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

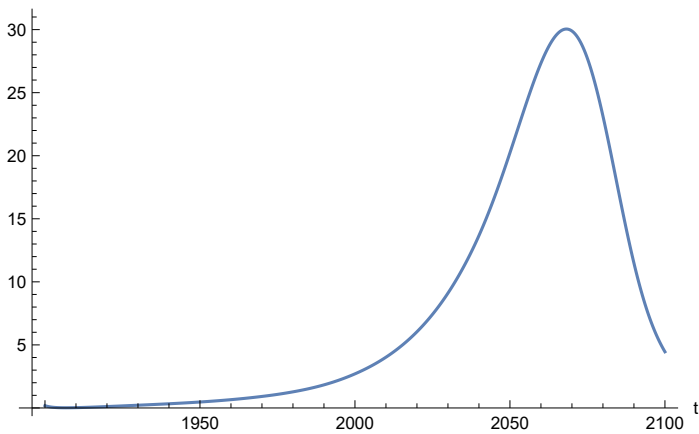
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 811.997
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 30.0451

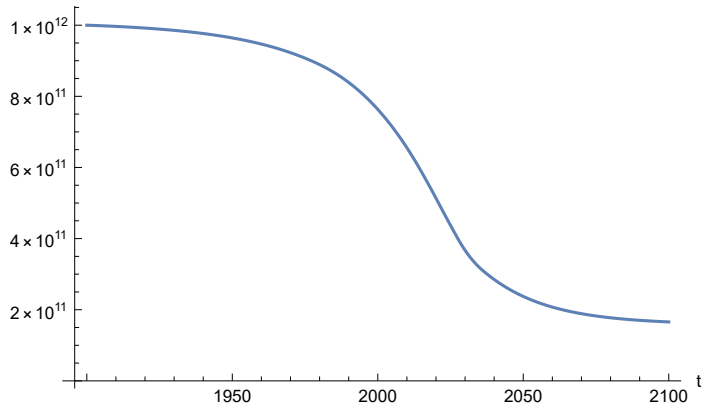
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 64. BENCHMARK SCENARIO 5, Experiment 64. LE = LE/1.1, t_policy_year = 1970.
Last modified: 29 July 2022/1550 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

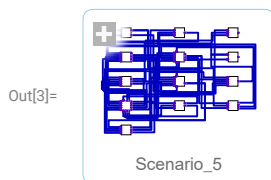
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

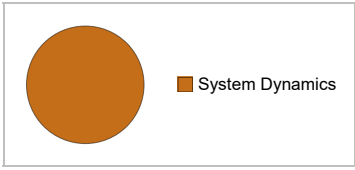
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 5.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_5"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_5
	Description	More accessible non-recoverable natural resources, pollution control, land yield enhancement, and erosion control
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background Color	True
Out[4]=	Simulation Length	265
	Simulation Length	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

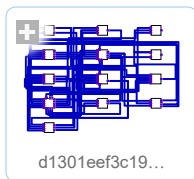
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

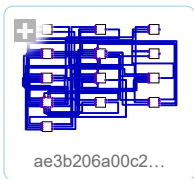
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set t_policy_year to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

```
Out[20]=
```




Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

SystemModelSimulate: At time 2088.8 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

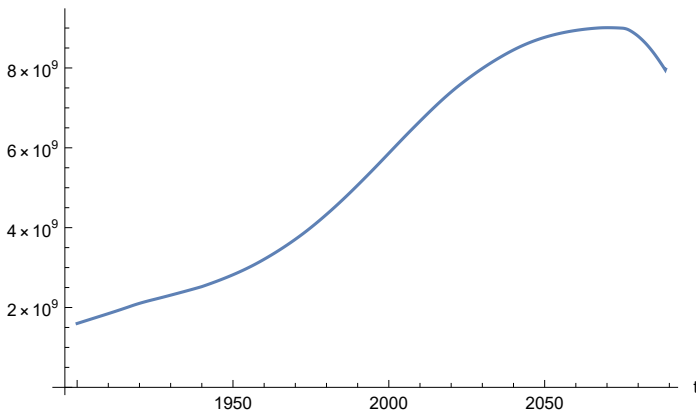
```
Out[21]=
```

```
SystemModelSimulationData [
   Model: Wae3b206a00c248a3b11eebe25614c3b9
  Time: 1.90 × 103 to 2090.
]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[22]=
```



Find max and min of population values.

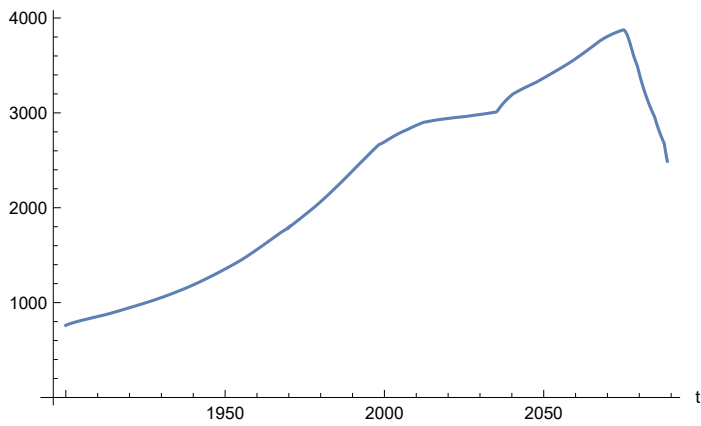
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 9.00864×10^9

Minimum is 1.6×10^9

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

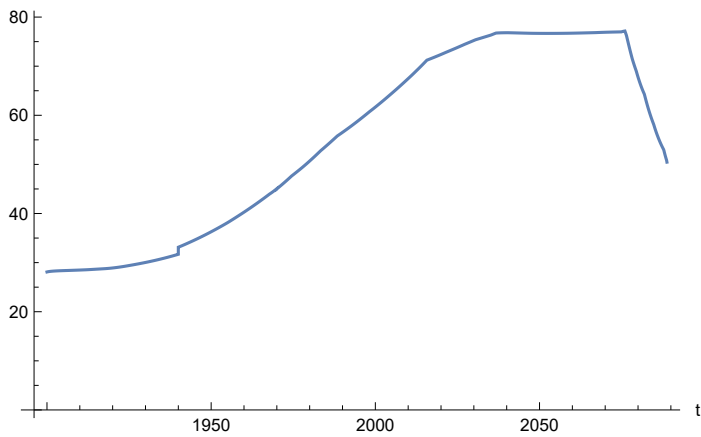
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[25]=

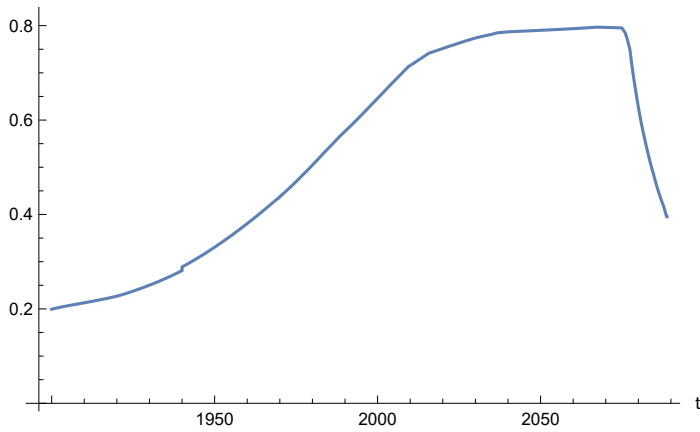


In[26]=

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

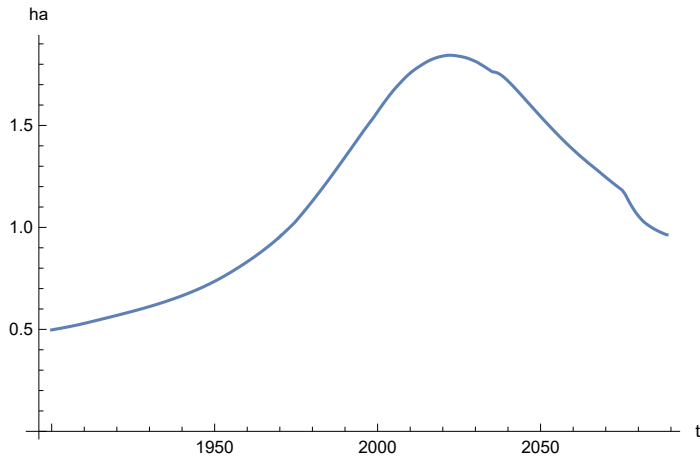
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

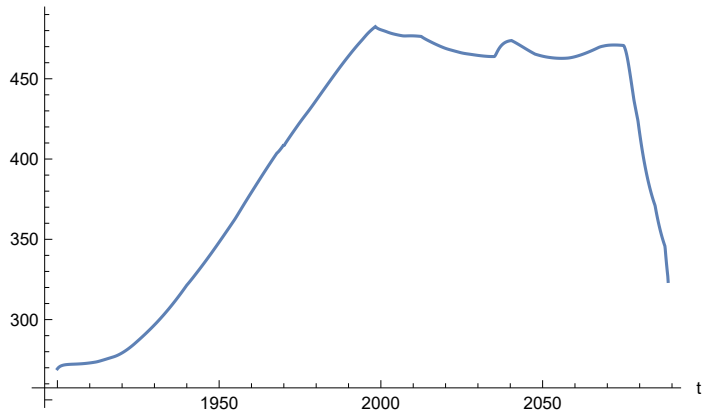
Out[28]=



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

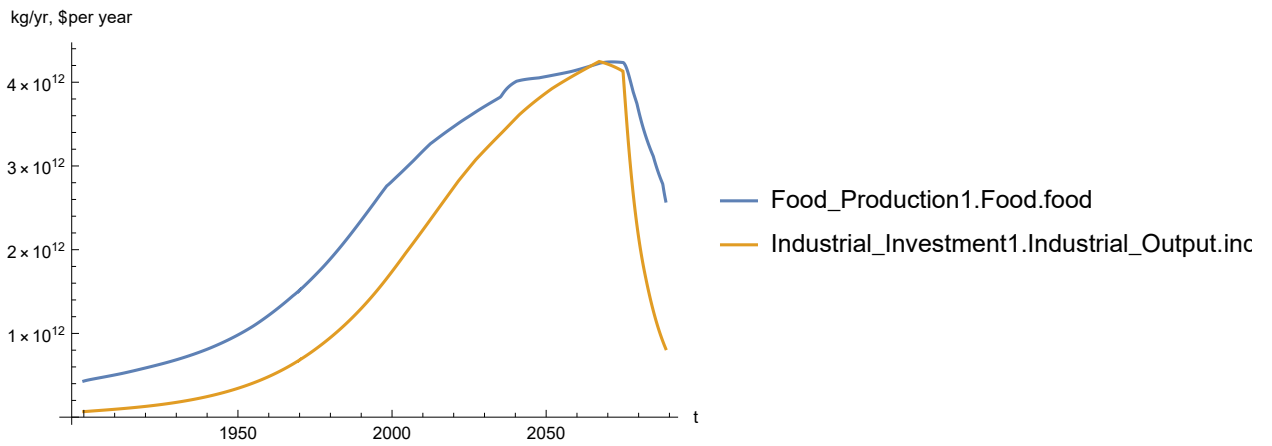
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

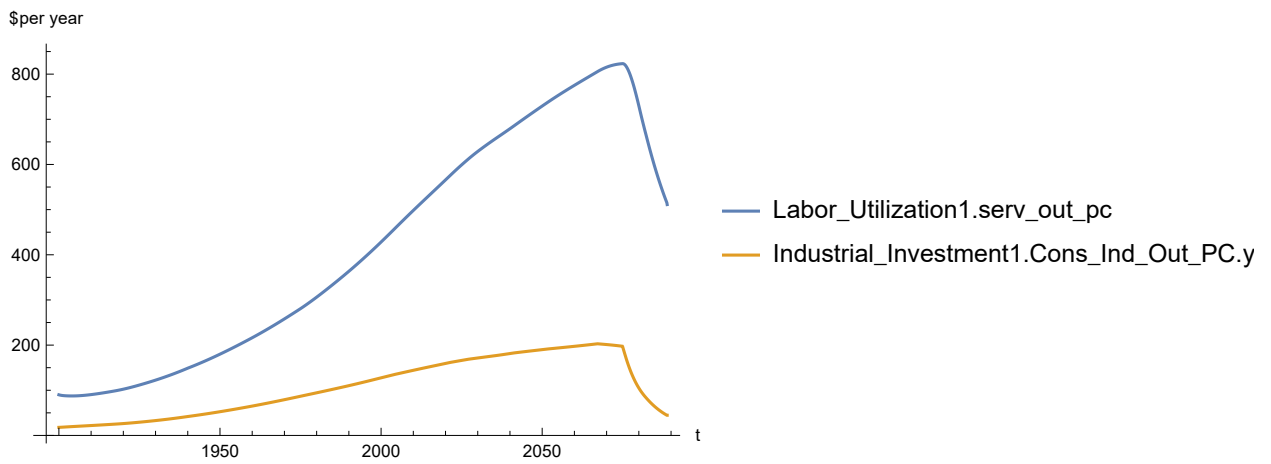
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

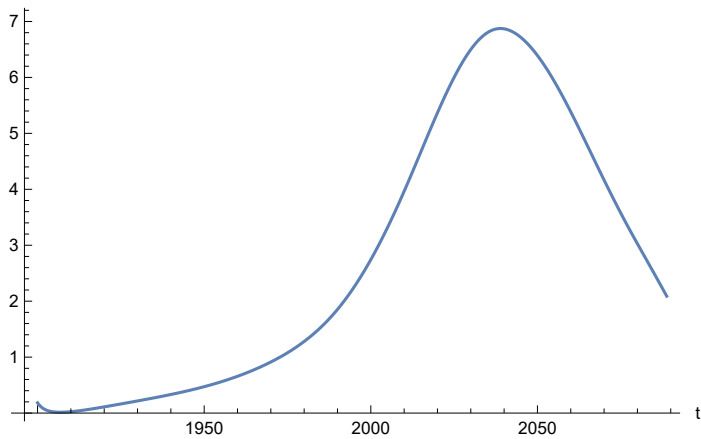
Maximum is 823.224

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

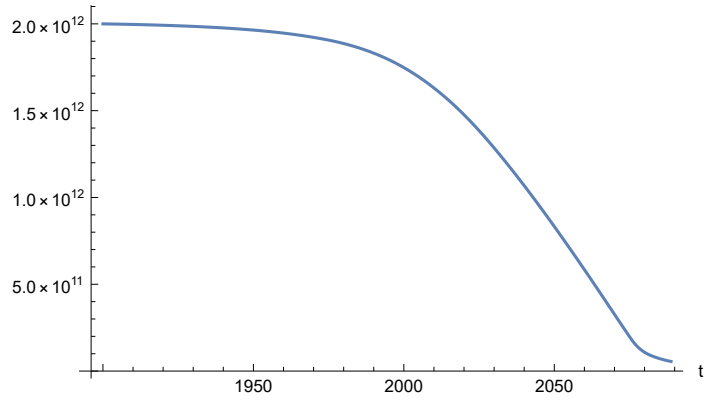
Maximum is 6.87429

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

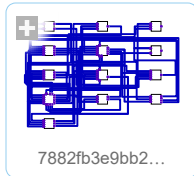


APPENDIX 65. LE/1.1, t_policy_year = 2025. Baseline Scenario 5, Experiment 65.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

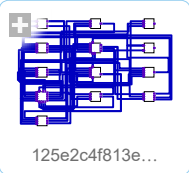
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

Out[44]=  125e2c4f813e...

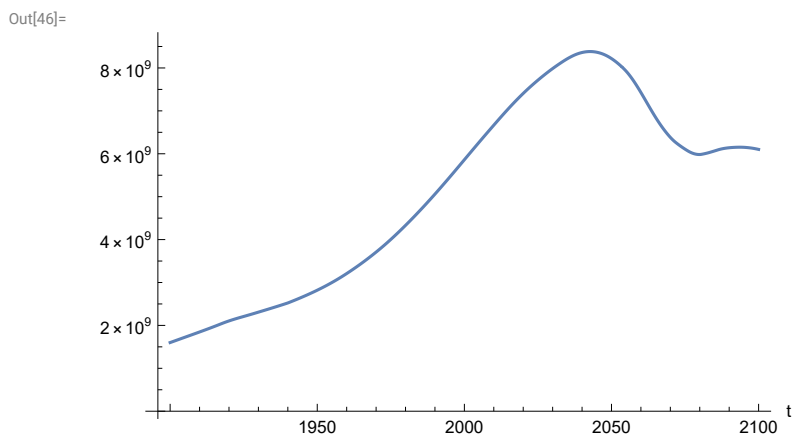
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W125e2c4f813e4250b893704e266b30b4
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

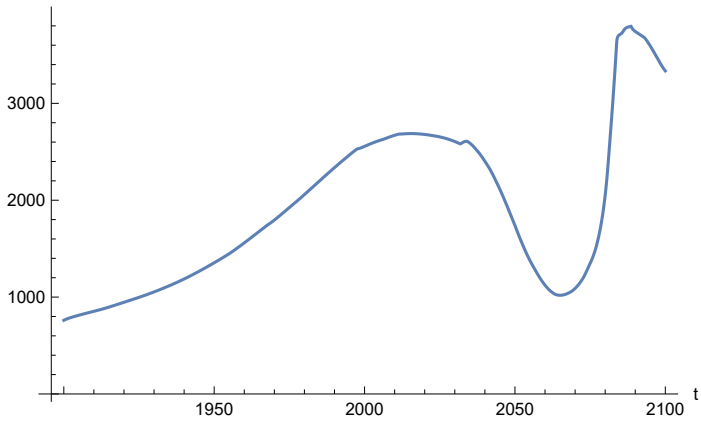
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 8.38234×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

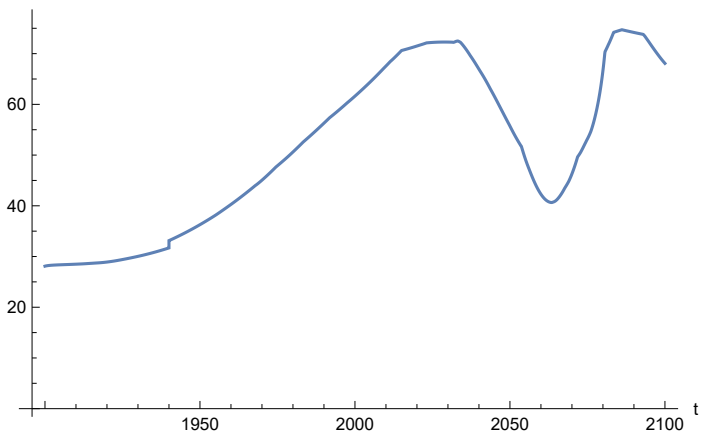
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

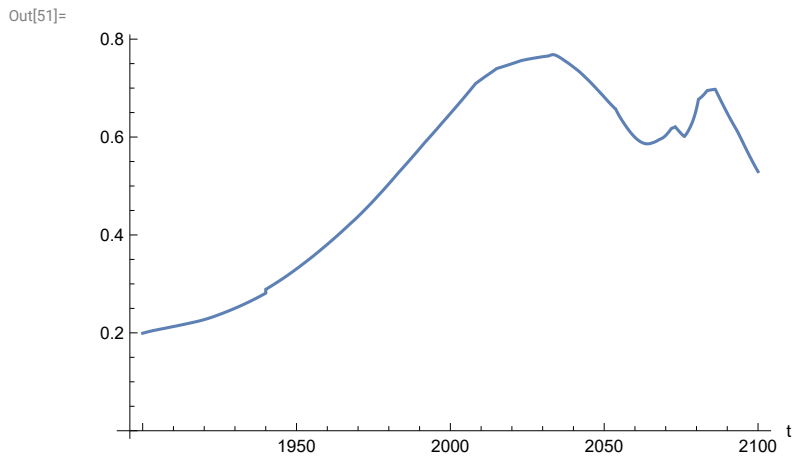
Out[49]=



In[50]:=

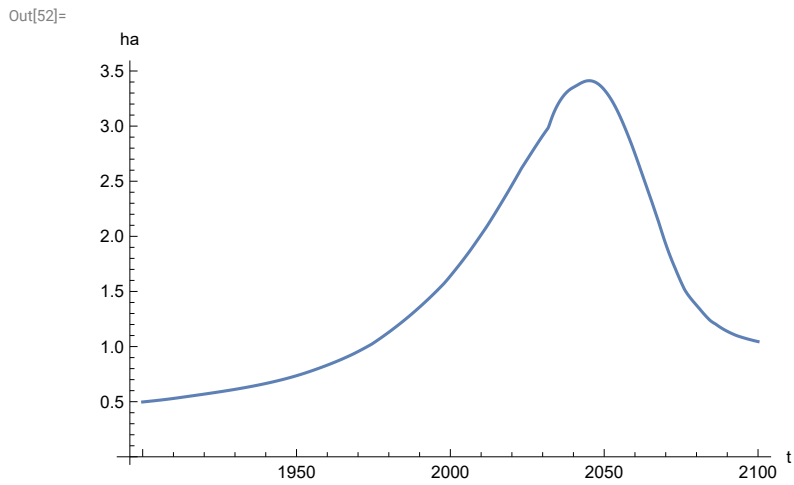
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

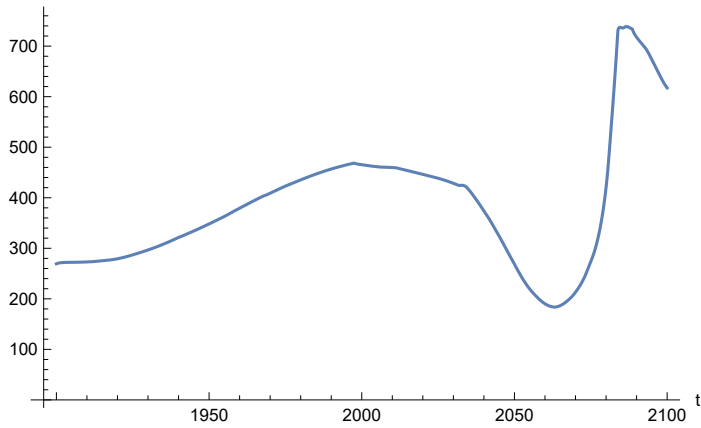
```
In[52]:= SystemModelPlot[basesim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

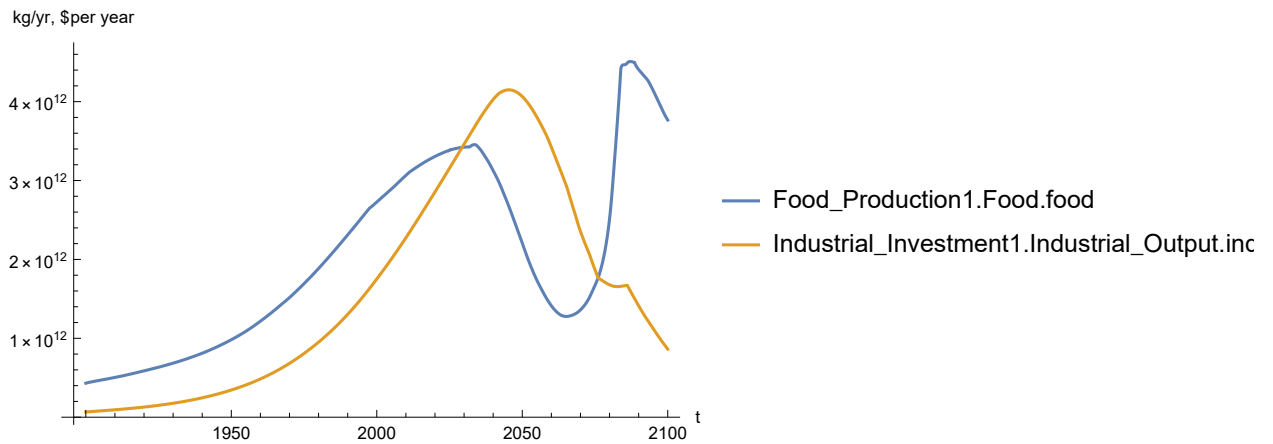
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

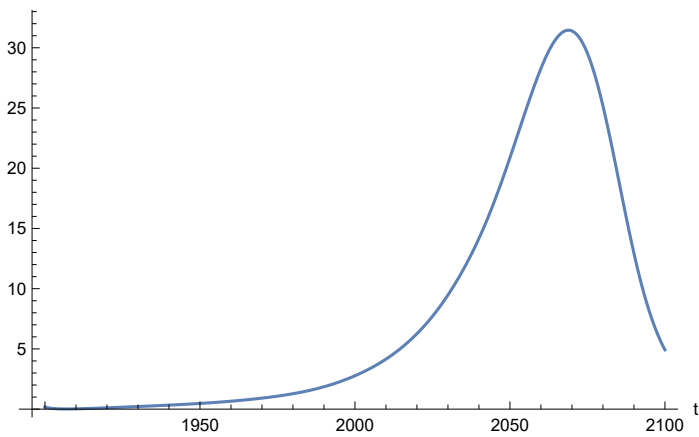


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 926.889
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



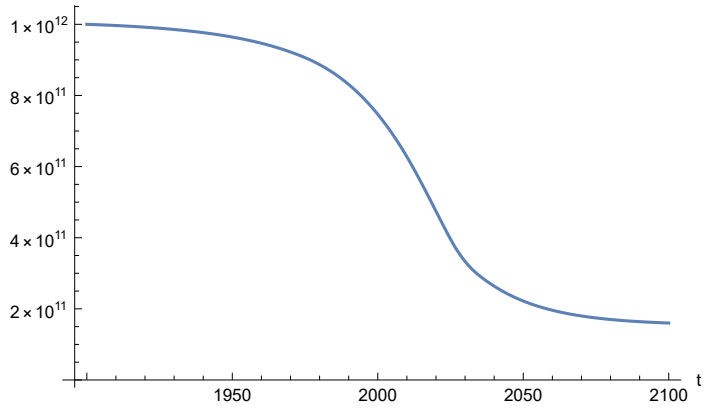
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 31.4575
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=



APPENDIX 5A1. BENCHMARK SCENARIO 8, Experiment 5A1. $LE = LE/1.001$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1210 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

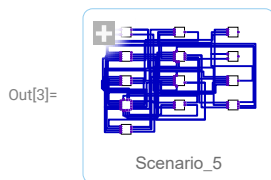
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

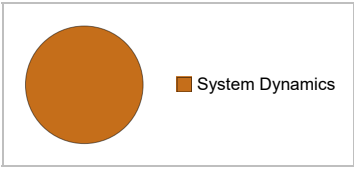
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 5.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_5"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_5
	D	More accessible non-recoverable natural resources, pollution control, land yield enhancement, and erosion control
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

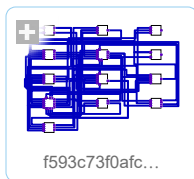
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```


```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}

In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
Out[18]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}

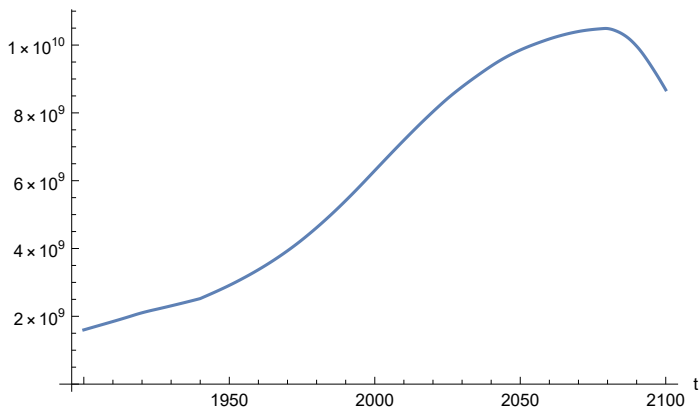
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
Out[19]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
Out[20]=
SystemModelSimulationData [  Model: Wf593c73f0afc47e790f3259f02e58e7d  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[21]=
```

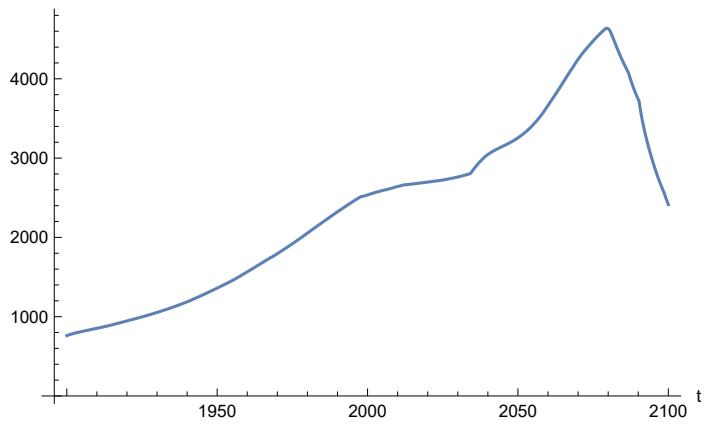


Find max and min of population values.

```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $1.04901 \times 10^{10}$ 
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

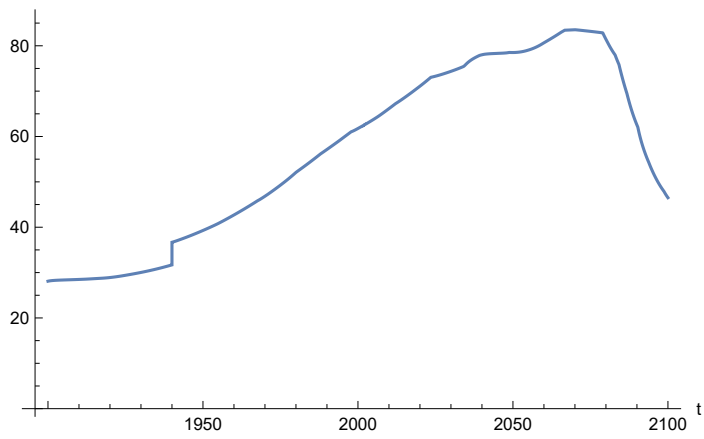
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

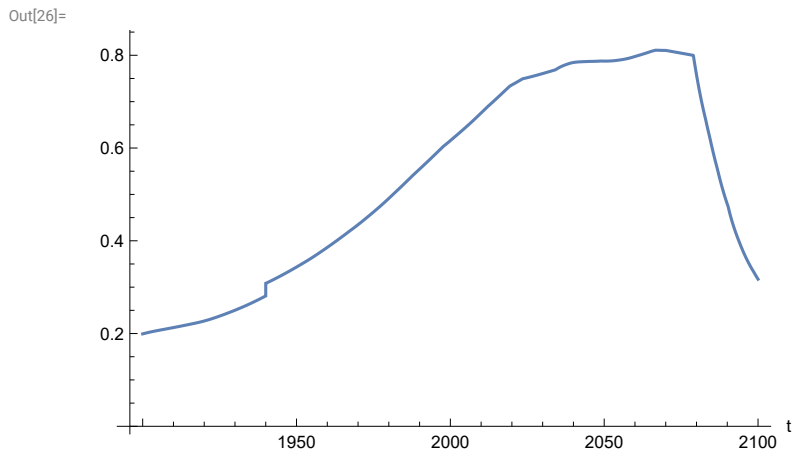
Out[24]=



In[25]:=

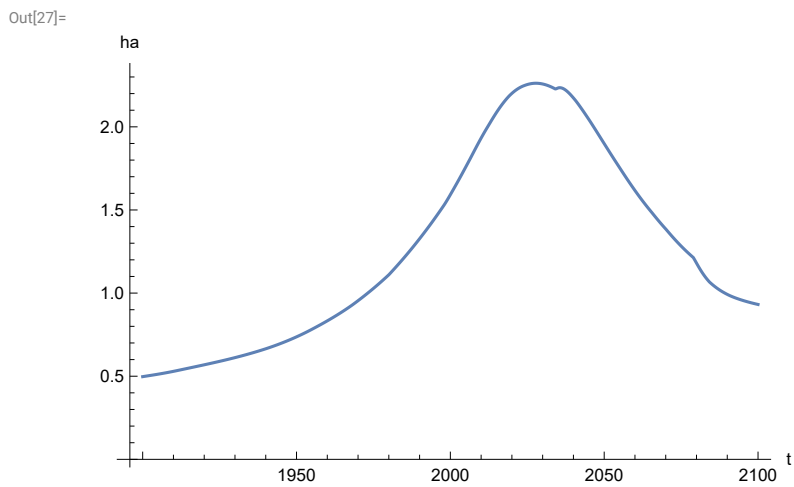
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

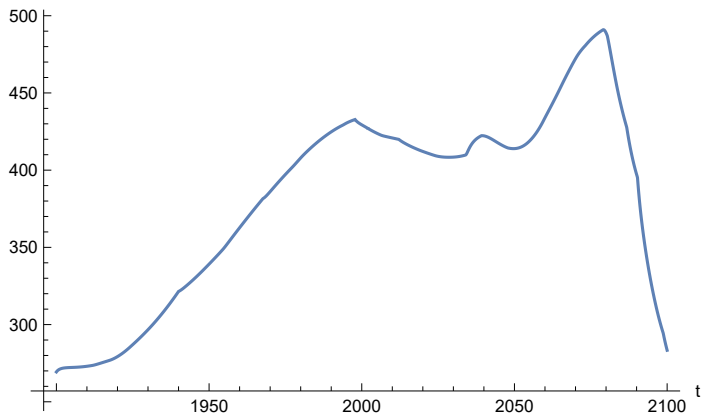
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

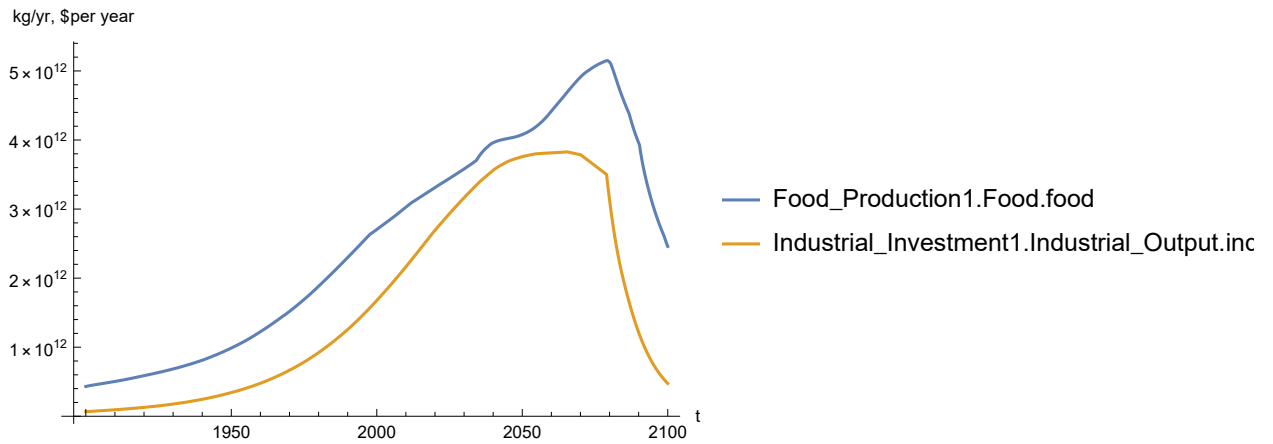
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

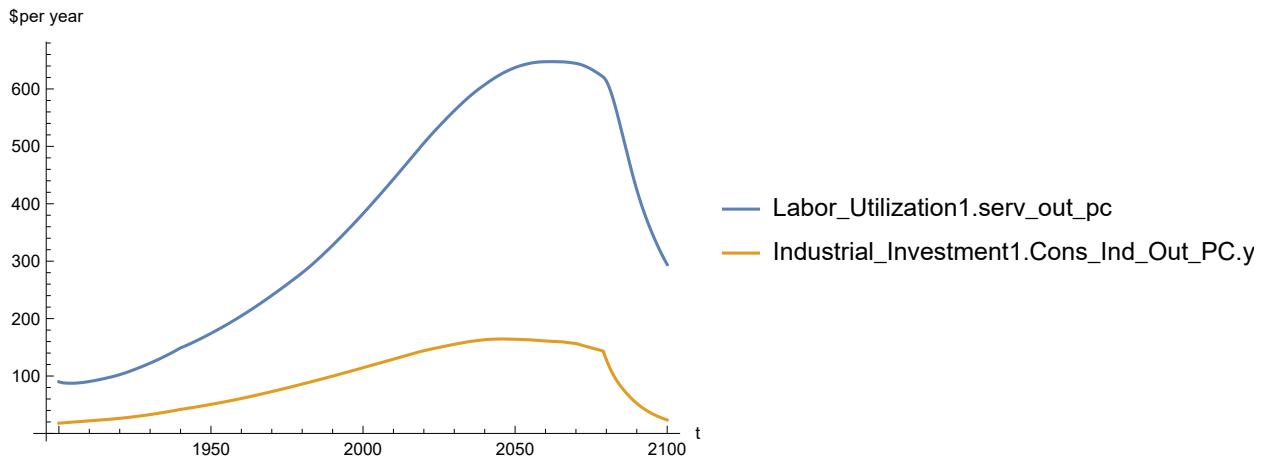
Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[30]=



Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

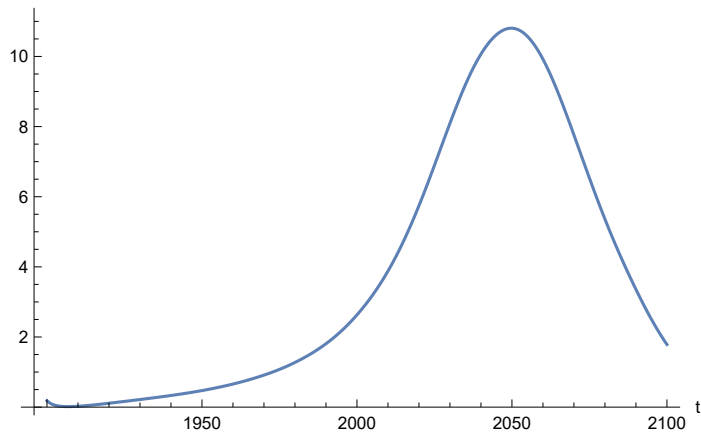
Maximum is 647.557

Minimum is 87.4451

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[32]=



Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

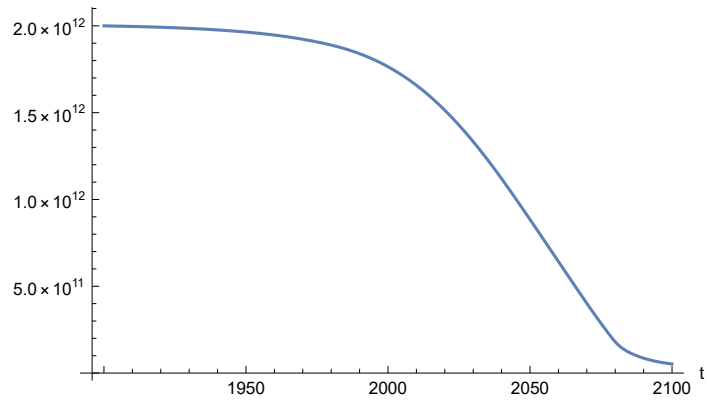
Maximum is 10.8051

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

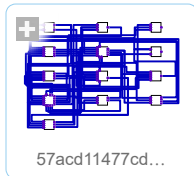


APPENDIX 5A2. LE/1.01, t_policy_year =2002. Baseline Scenario 8, Experiment 5A2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

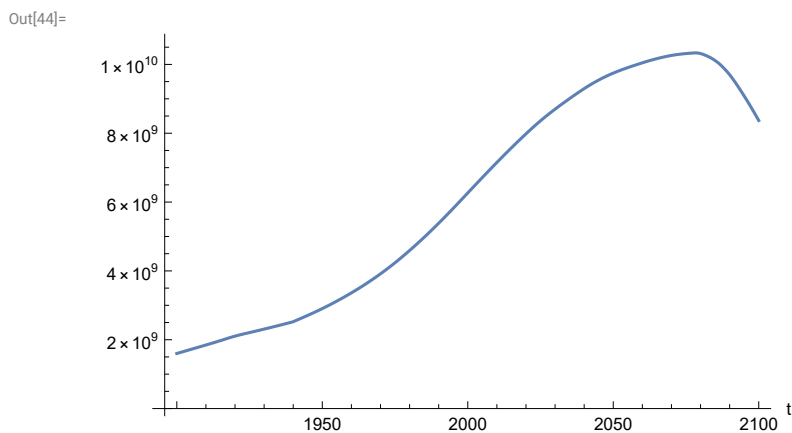
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [  Model: W57acd11477cd4f2bbacf3b5c3b647611  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

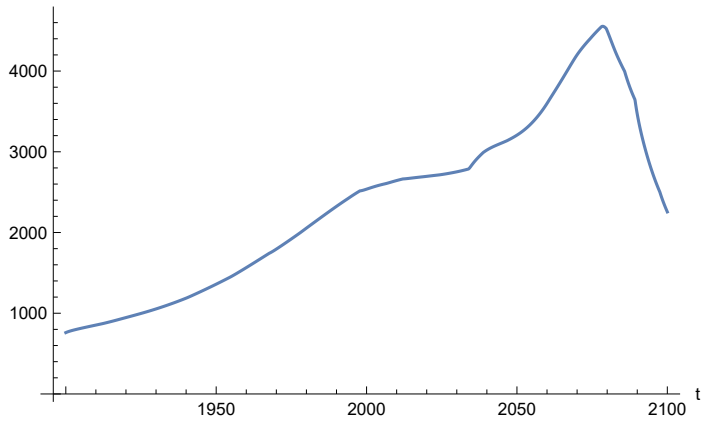
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $1.03345 \times 10^{10}$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

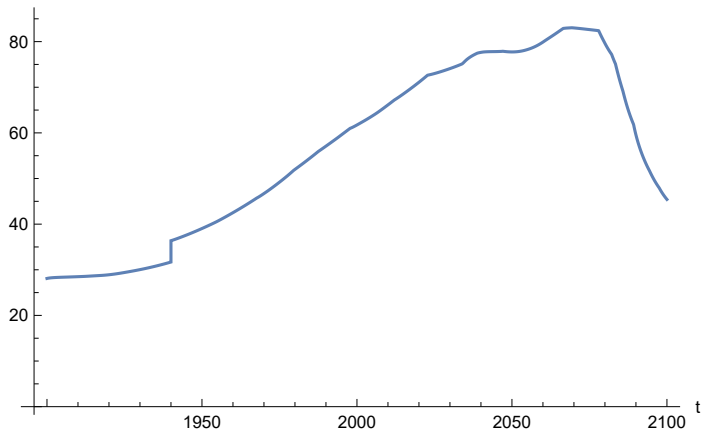
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

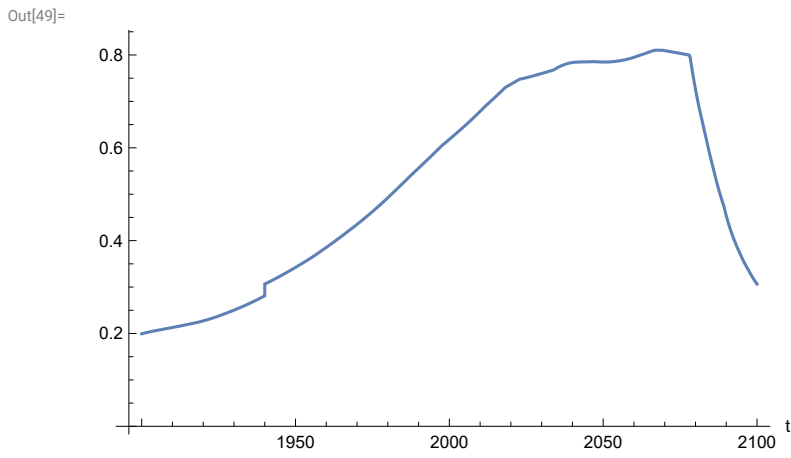
Out[47]=



In[48]:=

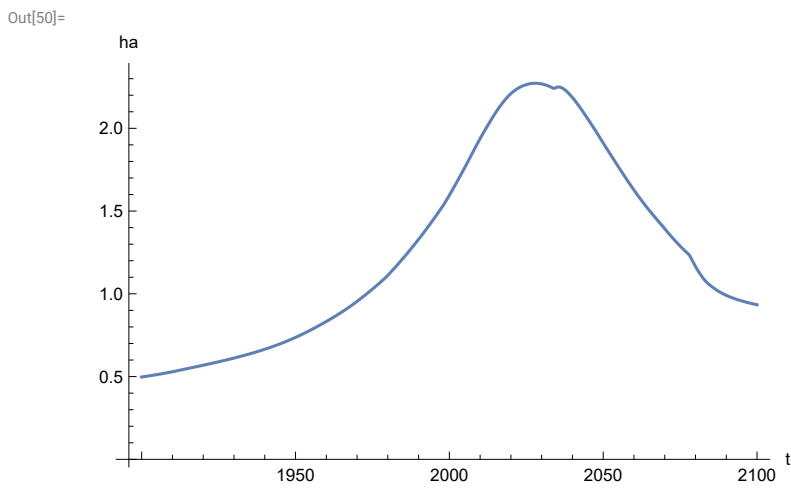
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

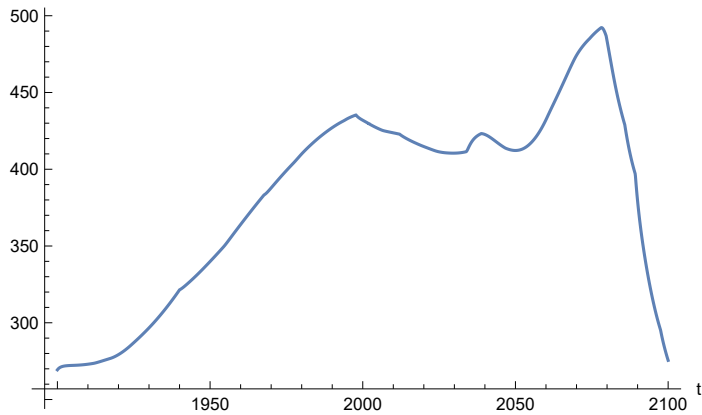
```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[51]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

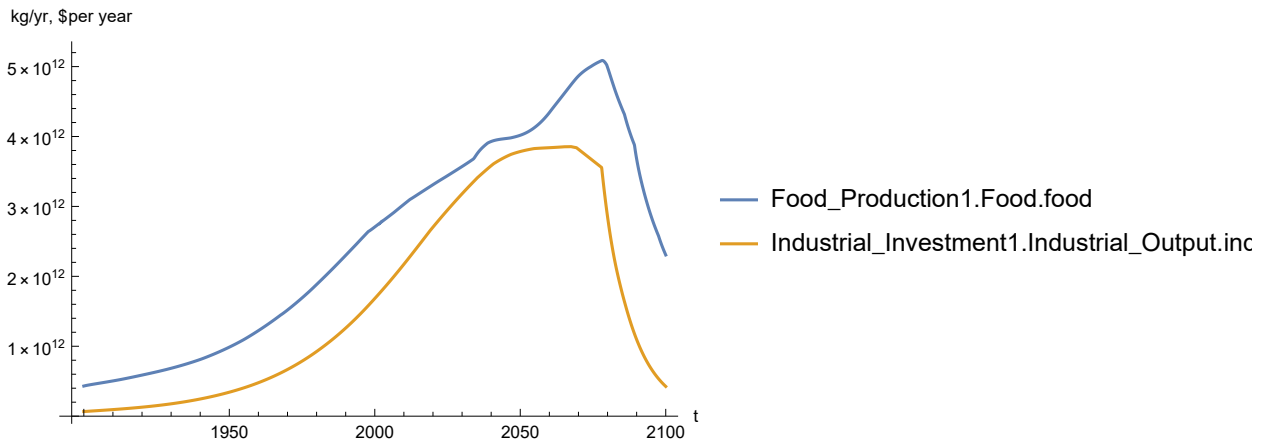
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

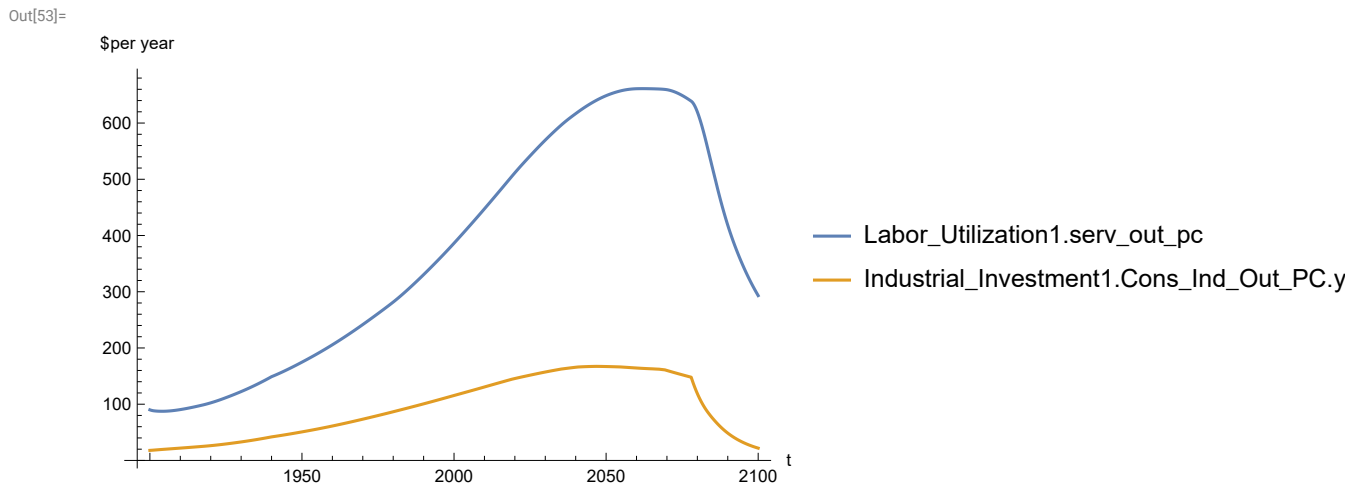
```
In[52]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

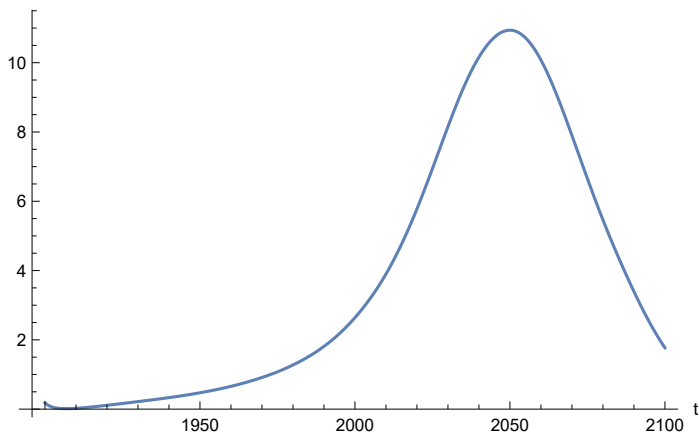


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 661.183
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



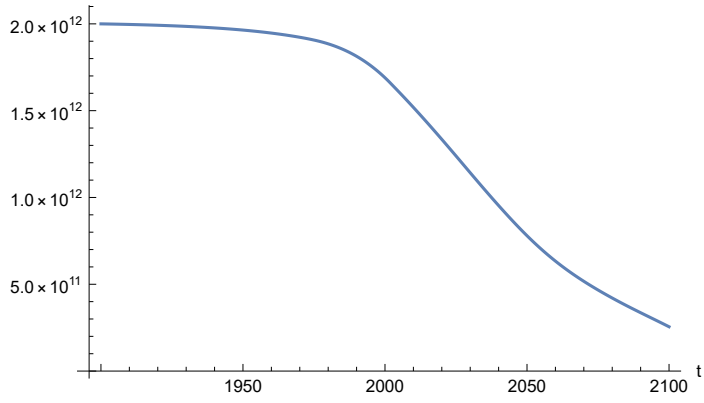
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.9377
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 5B1. BENCHMARK SCENARIO 8, Experiment 5B1. $LE = LE/1.03$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1225 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

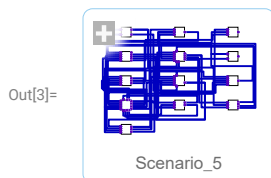
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

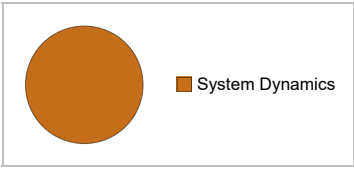
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 5.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_5"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_5
	D	More accessible non-recoverable natural resources, pollution control, land yield enhancement, and erosion
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

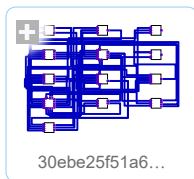
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```


```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

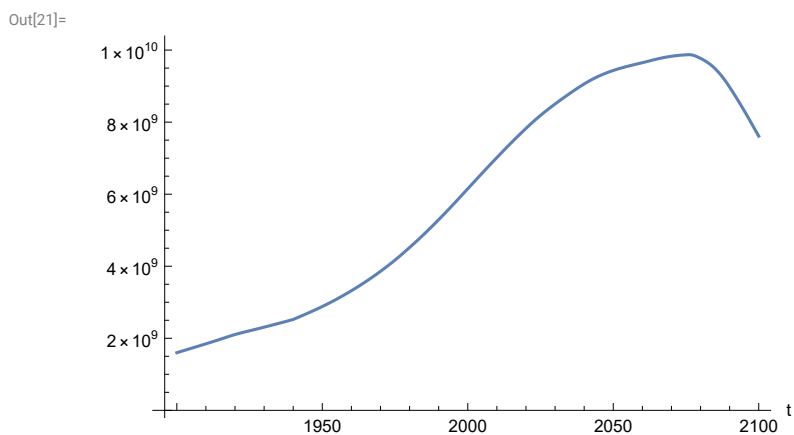
Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

```
Out[20]= SystemModelSimulationData [
   Model: W30ebe25f51a640e0a441092503d03adf
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

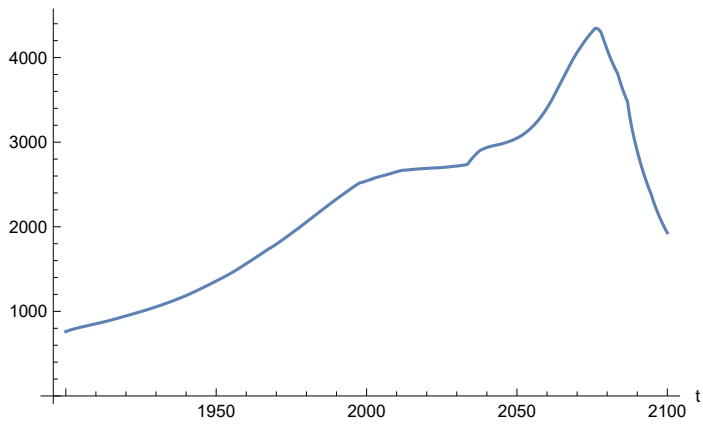
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.87281 × 109
```

```
Minimum is 1.6 × 109
```

In[23]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

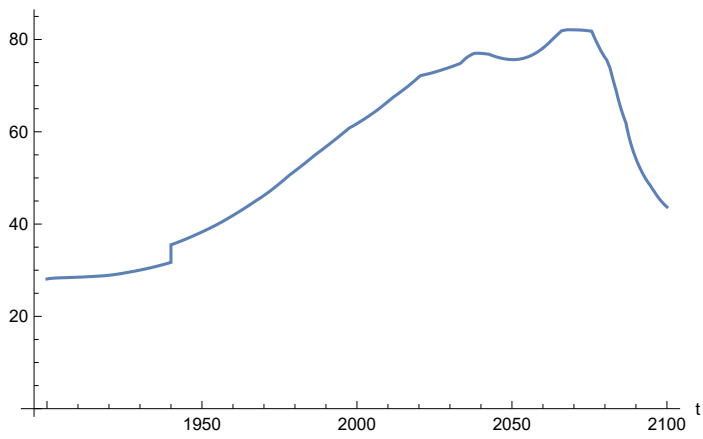
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

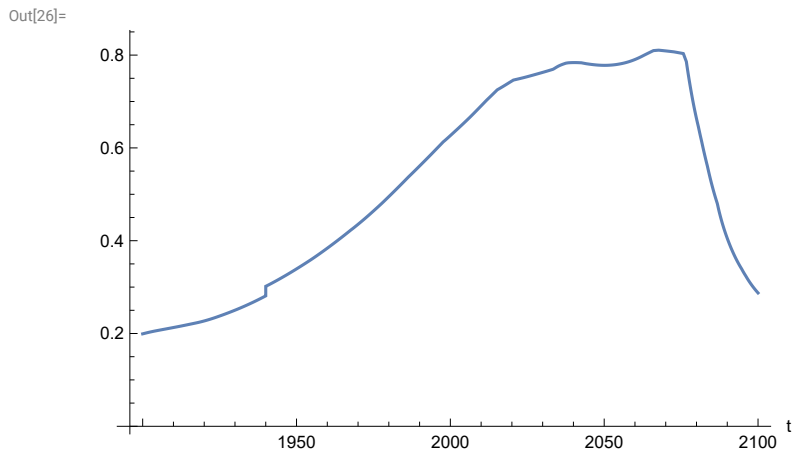
Out[24]=



In[25]:=

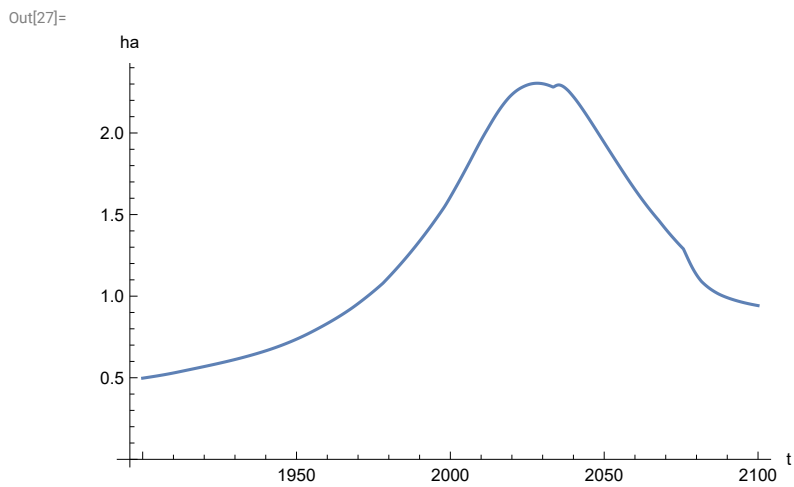
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

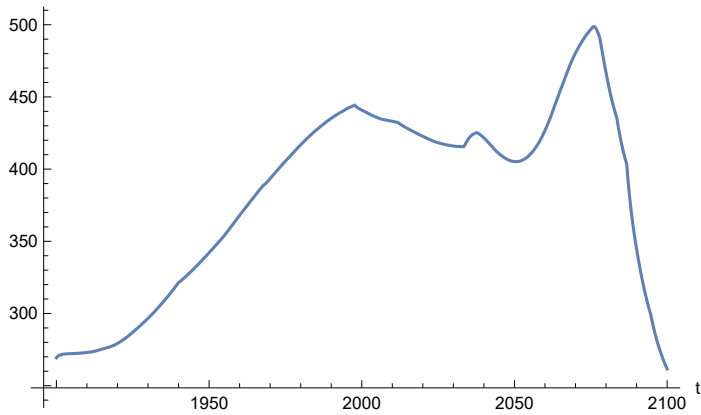
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

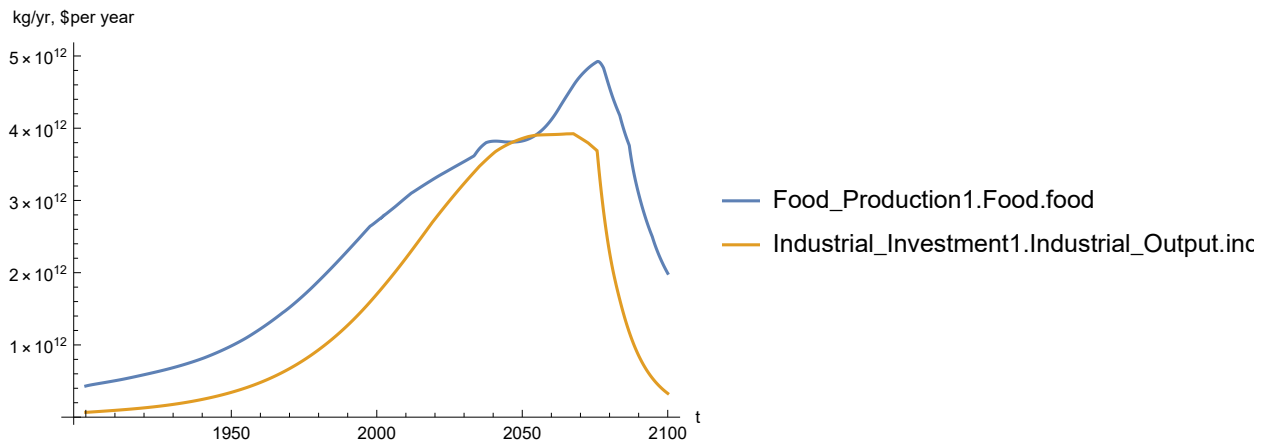
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

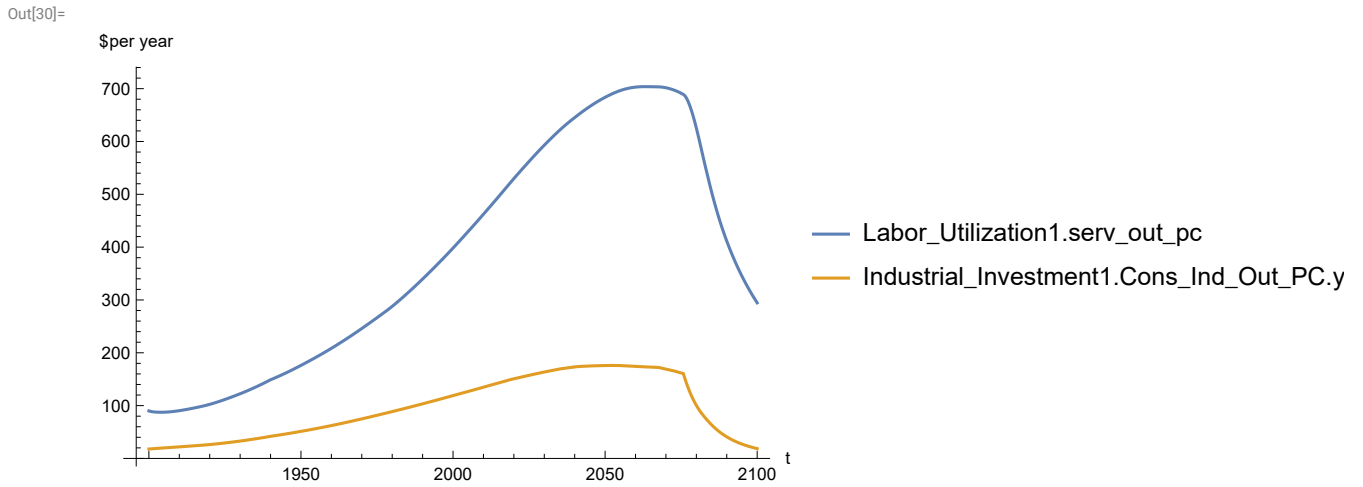
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

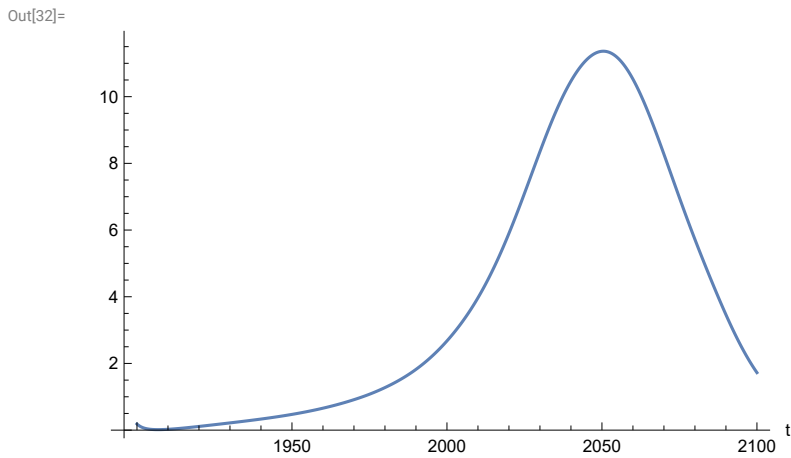


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 703.806
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



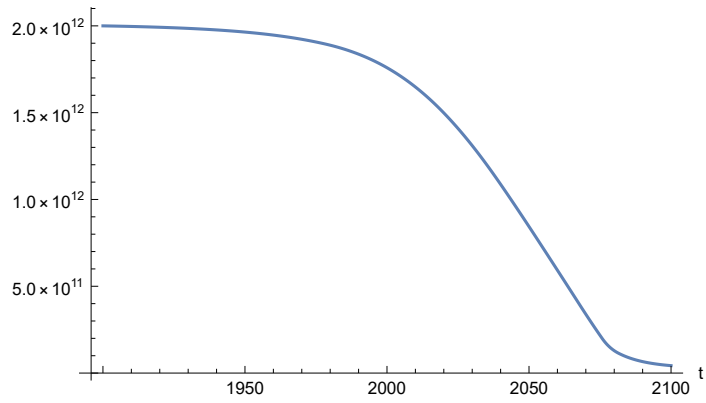
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.3629
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

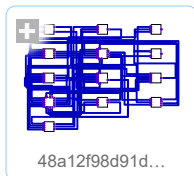


APPENDIX 5B2. LE/1.05, t_policy_year = 2002. Baseline Scenario 8, Experiment 5B2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=


```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

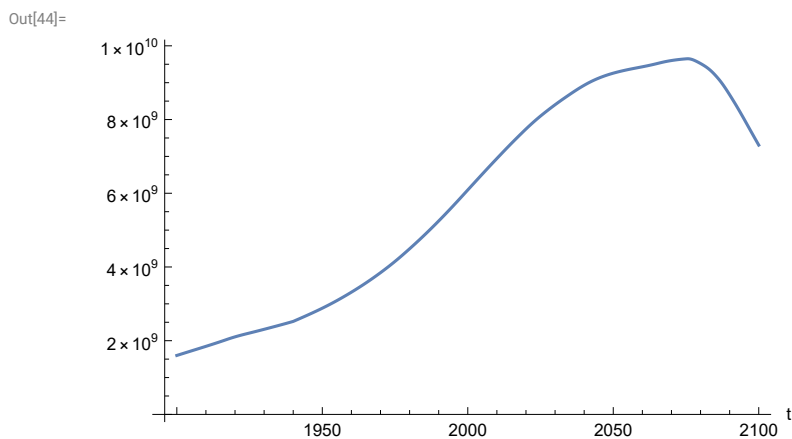
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: W48a12f98d91d49f18c002fffbef5579e
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

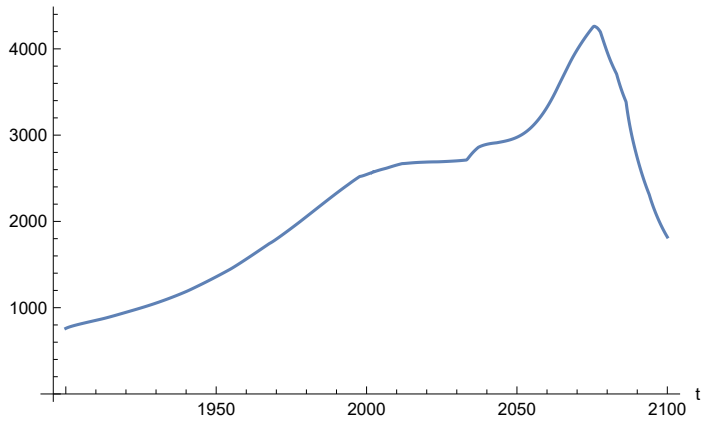
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.64931 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

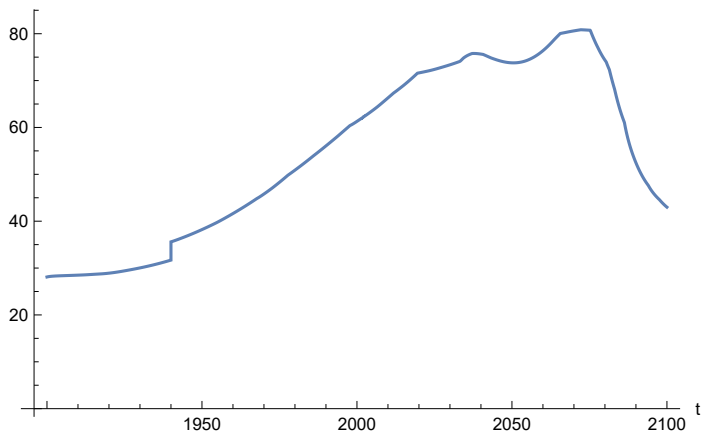
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

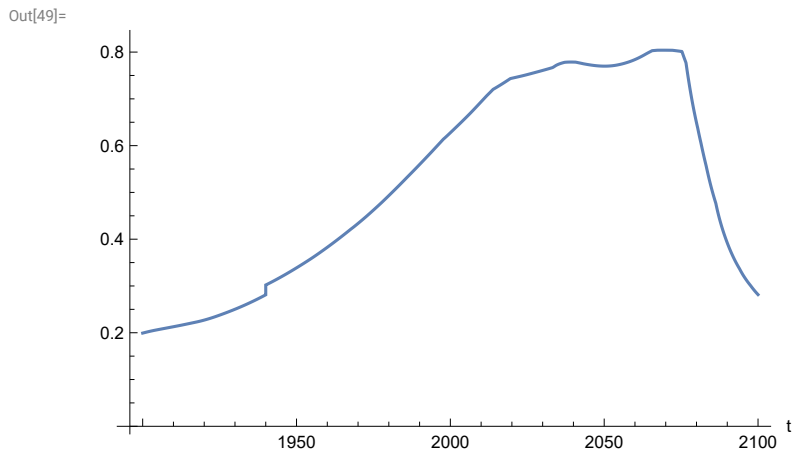
Out[47]=



In[48]:=

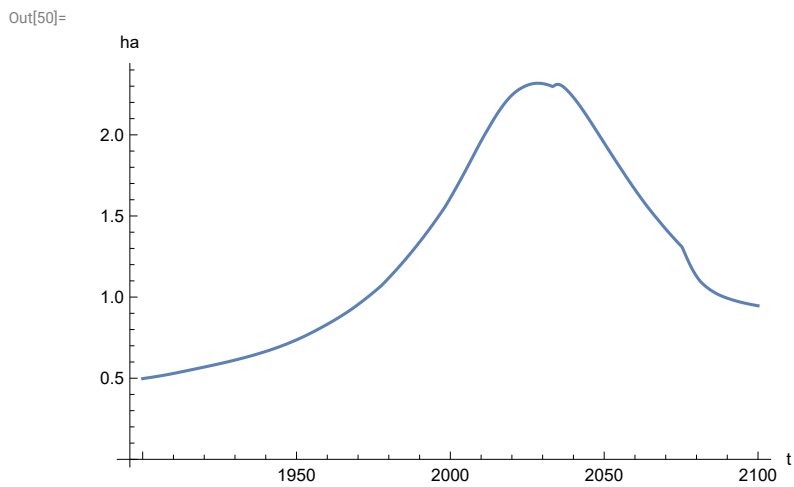
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

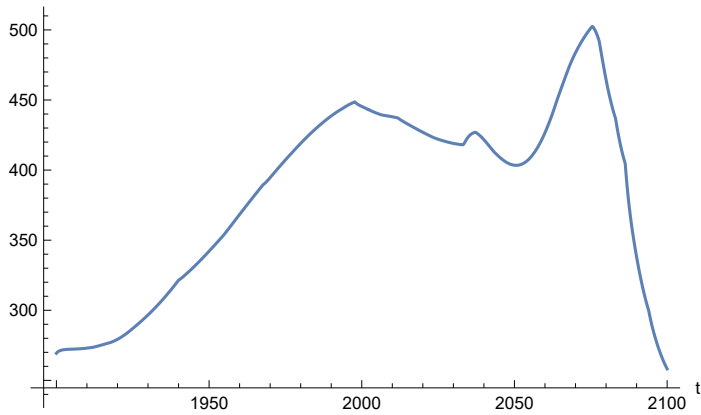
```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[51]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

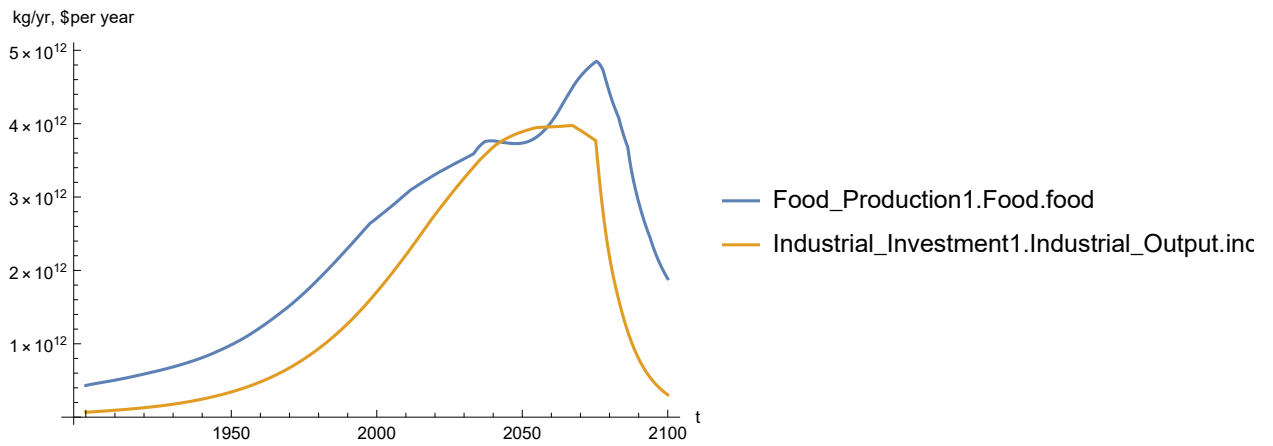
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

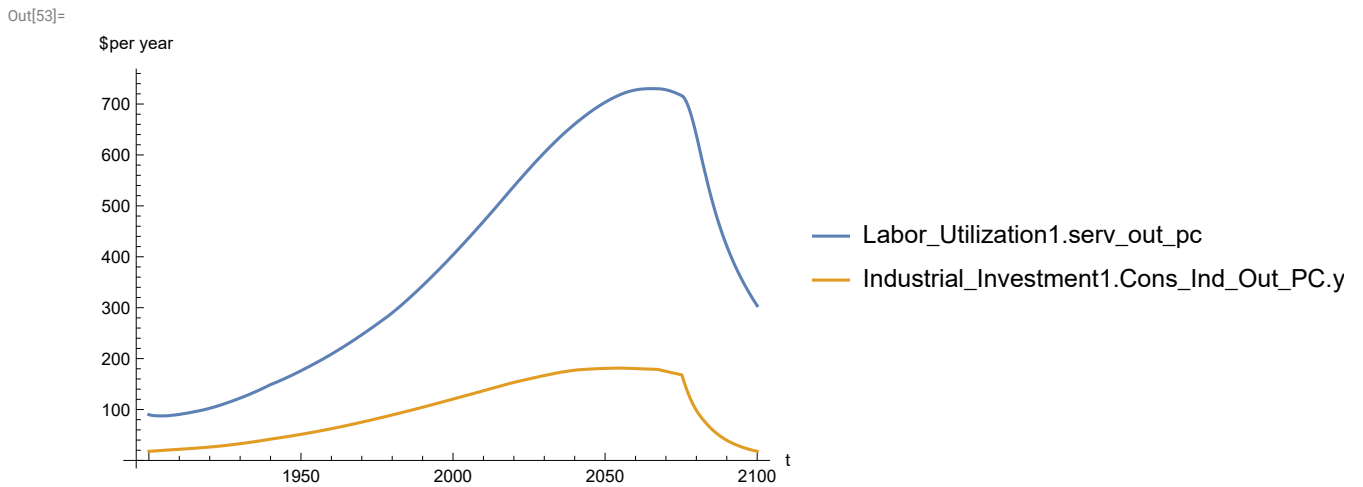
```
In[52]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

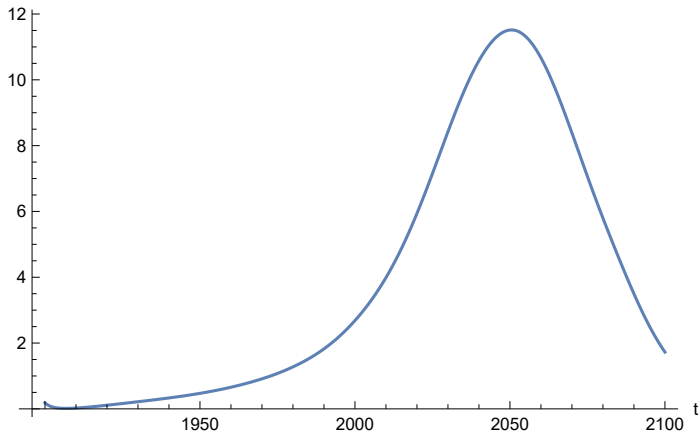


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 730.211
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



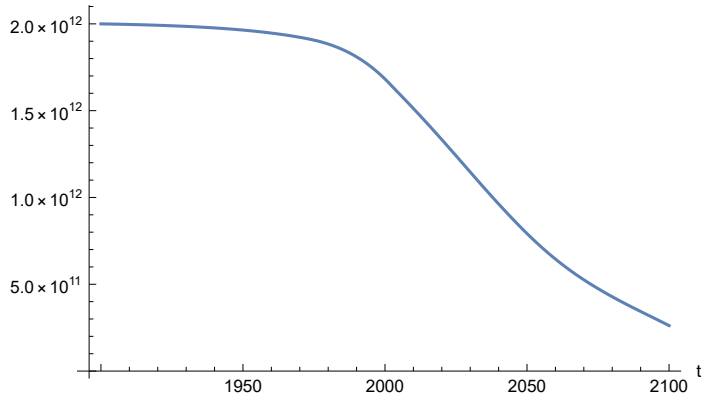
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.5155
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 5C1. BENCHMARK SCENARIO 8, Experiment 5C1. $LE = LE/1.1$, $t_policy_year = 2002$.

Last modified: 1 August 2022/1230 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

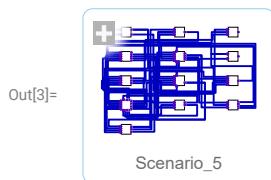
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

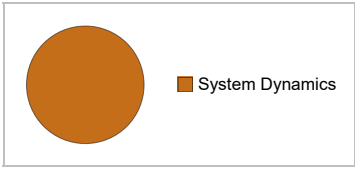
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 5.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_5"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_5
	D	More accessible non-recoverable natural resources, pollution control, land yield enhancement, and erosion control
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

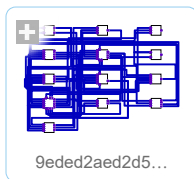
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

⋯ **SystemModelSimulate**: At time 2084. s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

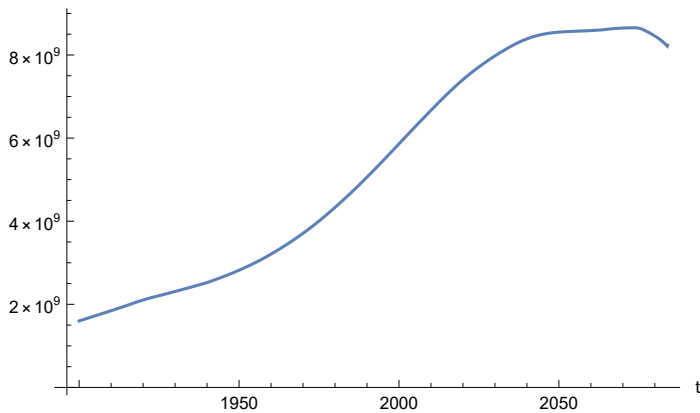
```
Out[20]=
```

```
SystemModelSimulationData [  Model: W9eded2aed2d540bf81de67310f5a2118
Time: 1.90 × 103 to 2.08 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

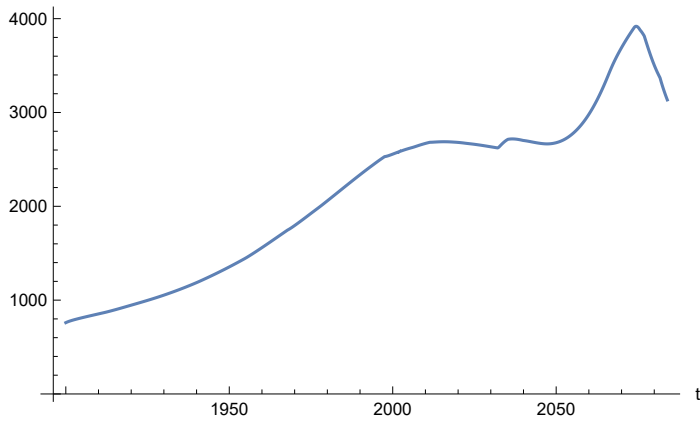
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.65451 × 109
```

```
Minimum is 1.6 × 109
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

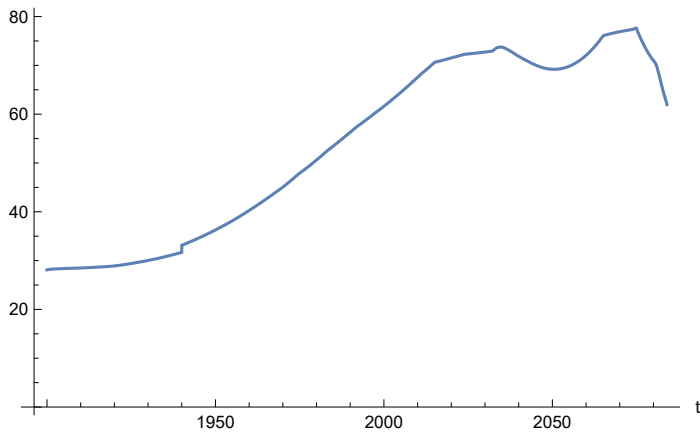
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

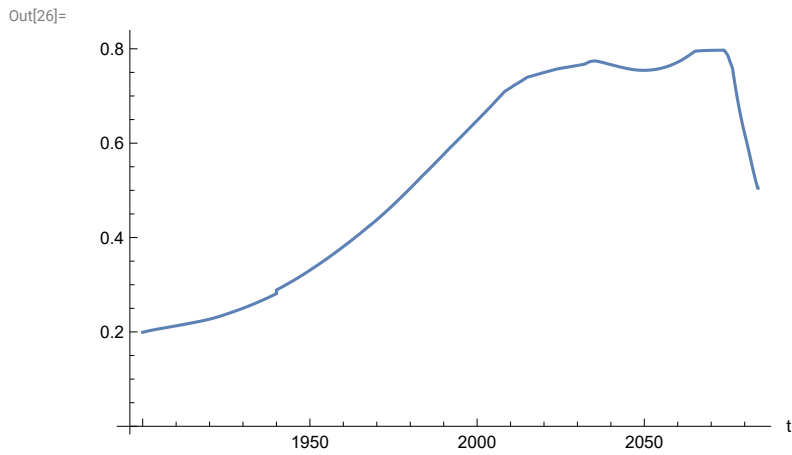
Out[24]=



In[25]:=

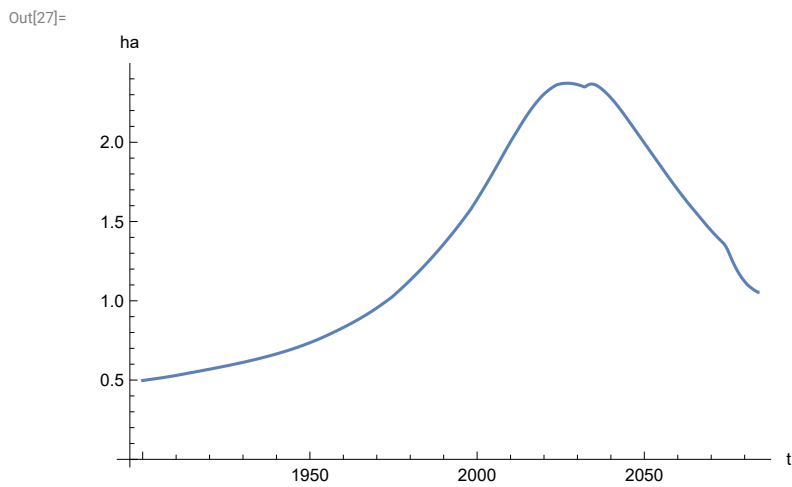
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

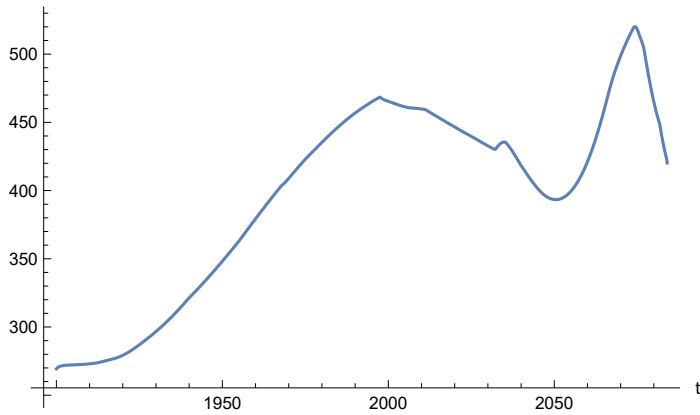
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

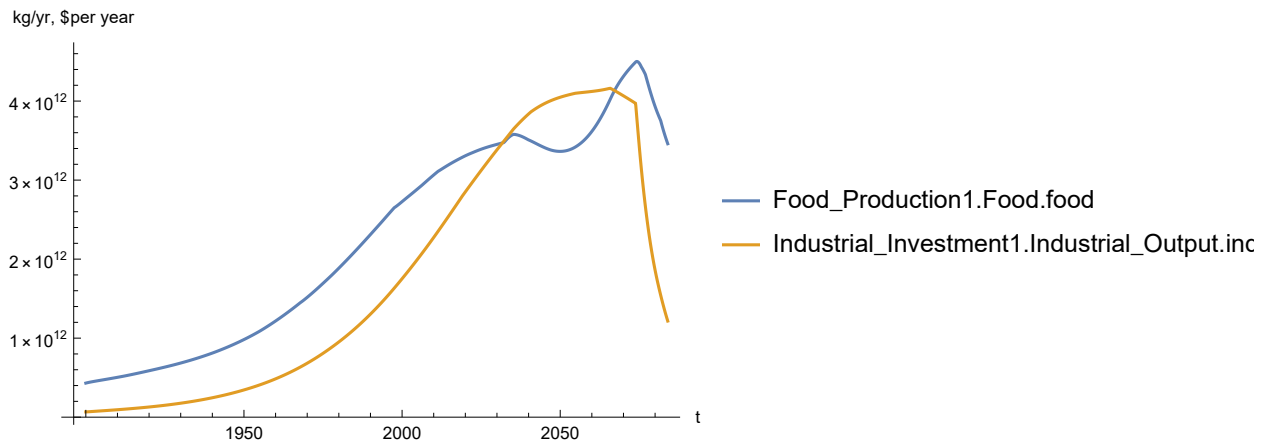
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

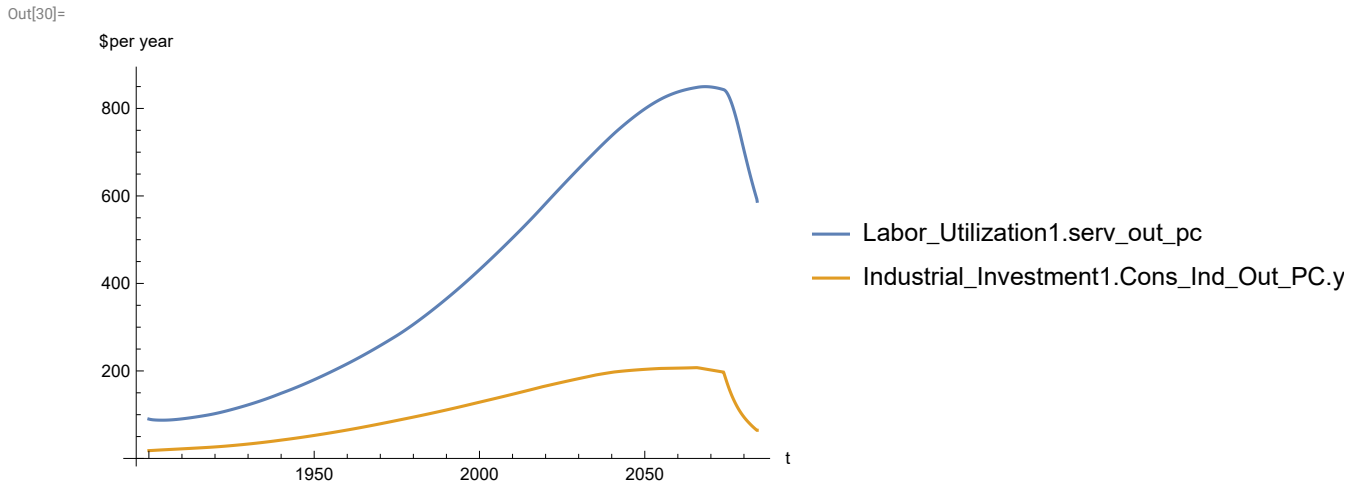
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

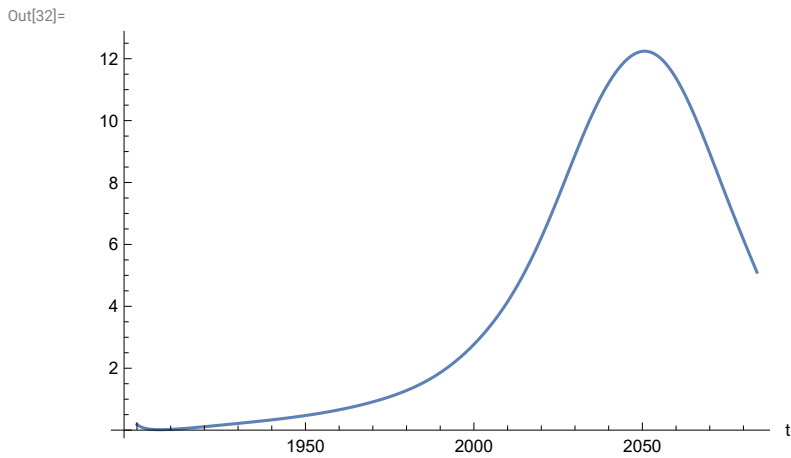


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 849.814
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

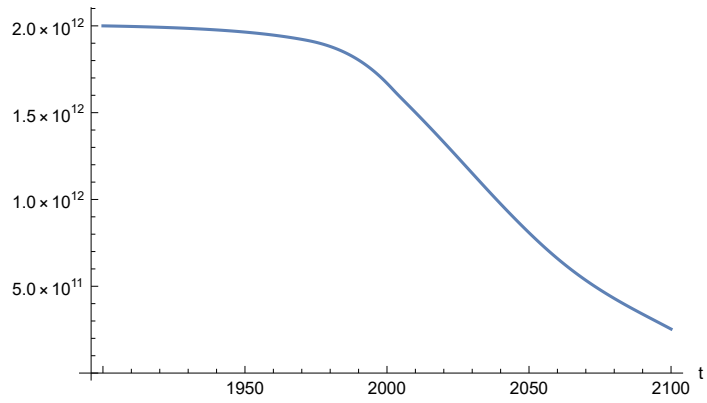


Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 12.242
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[ ]=
```



APPENDIX 66. BENCHMARK SCENARIO 6, Experiment 66. `t_policy_year = 2002.`

Last modified: 30 July 2022/0945 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

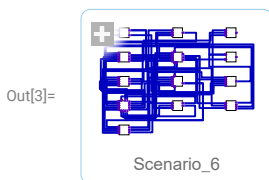
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

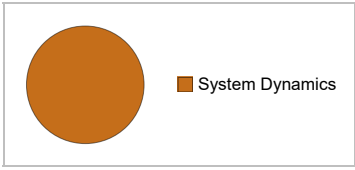
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Benchmark Scenario 6.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_6"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_6
	Description	More accessible non-recoverable natural resources, pollution control, land yield enhancement, erosion pro
	Simulation Interval	True
	Policy Year	0
	Control Cost	106
	Base Case	True
Out[4]=	Simulation Years	265
	Simulation Years	265
	Description	

Show the default value of `t_policy_year`.

```
In[5]:= SystemModel[mysim][{"ParameterValues", "t_policy_year"}]
```

```
Out[5]= {t_policy_year → 2002}
```

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

```
In[6]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[7]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[8]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[9]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute Benchmark Scenario 1 and plot various variables

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

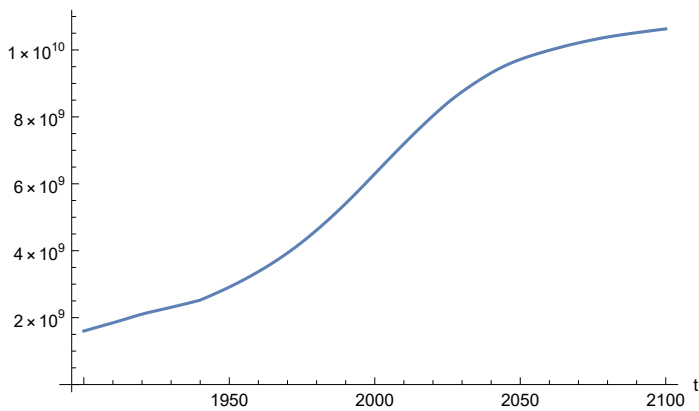
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Scenario_6
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



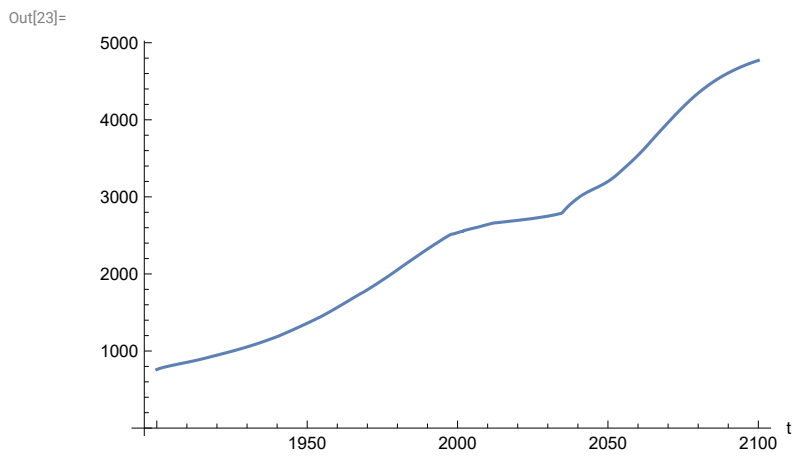
Find max and min of population values.

```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $1.06293 \times 10^{10}$ 
```

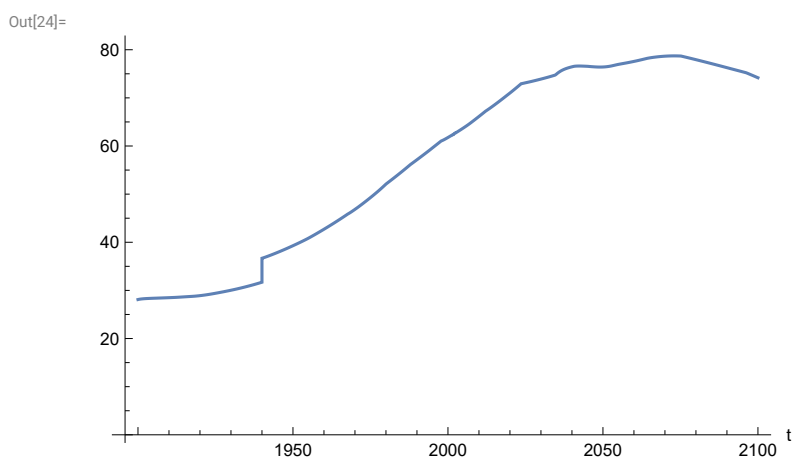
```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]



Plot life expectancy, years.

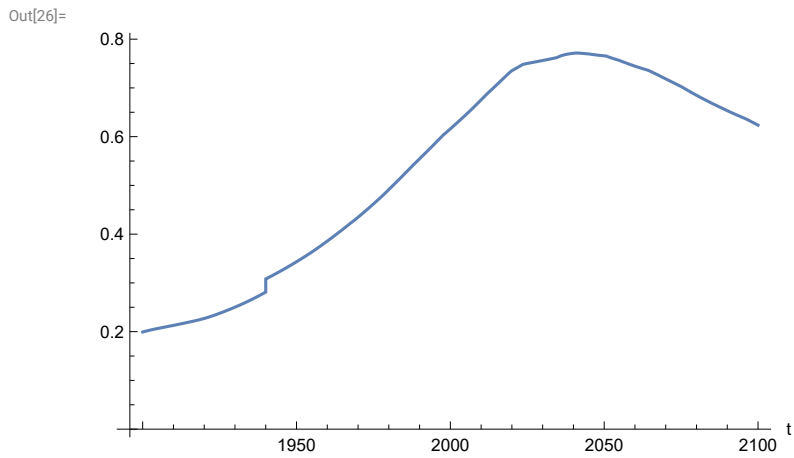
In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]



In[25]:=

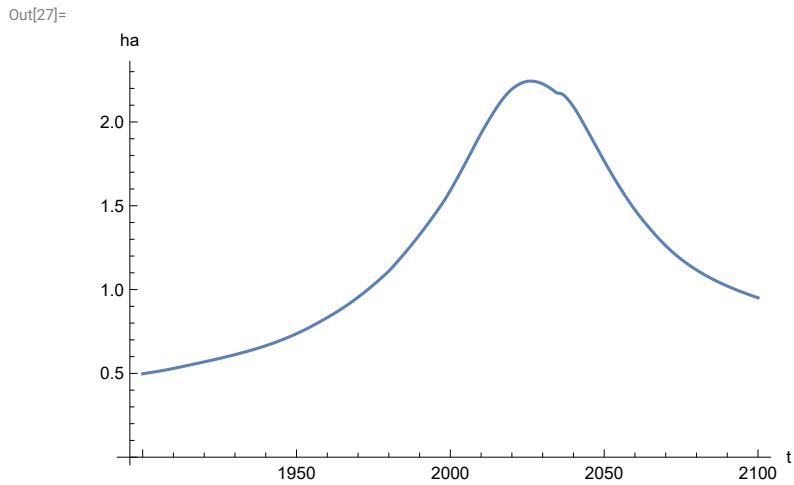
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

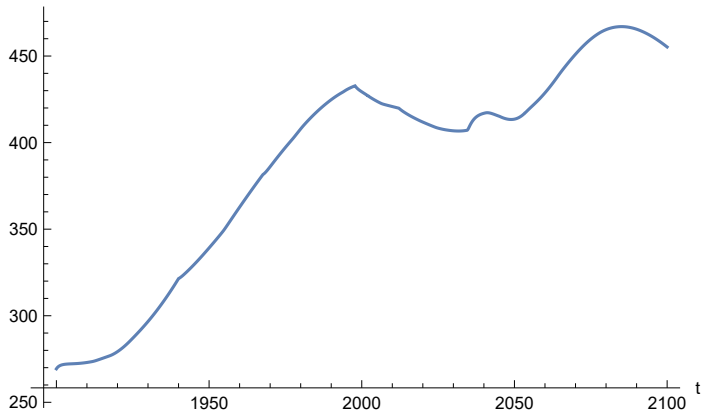
```
In[27]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]**

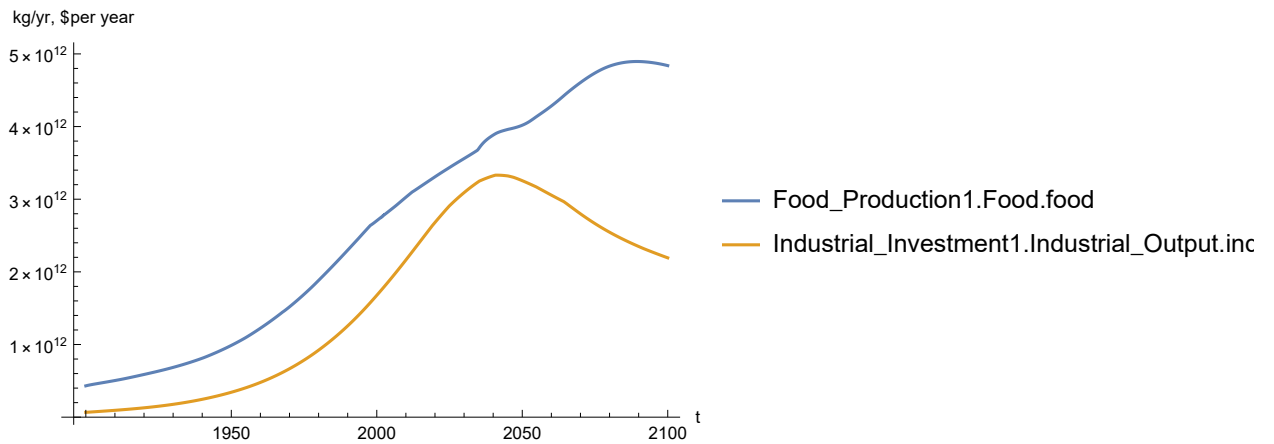
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

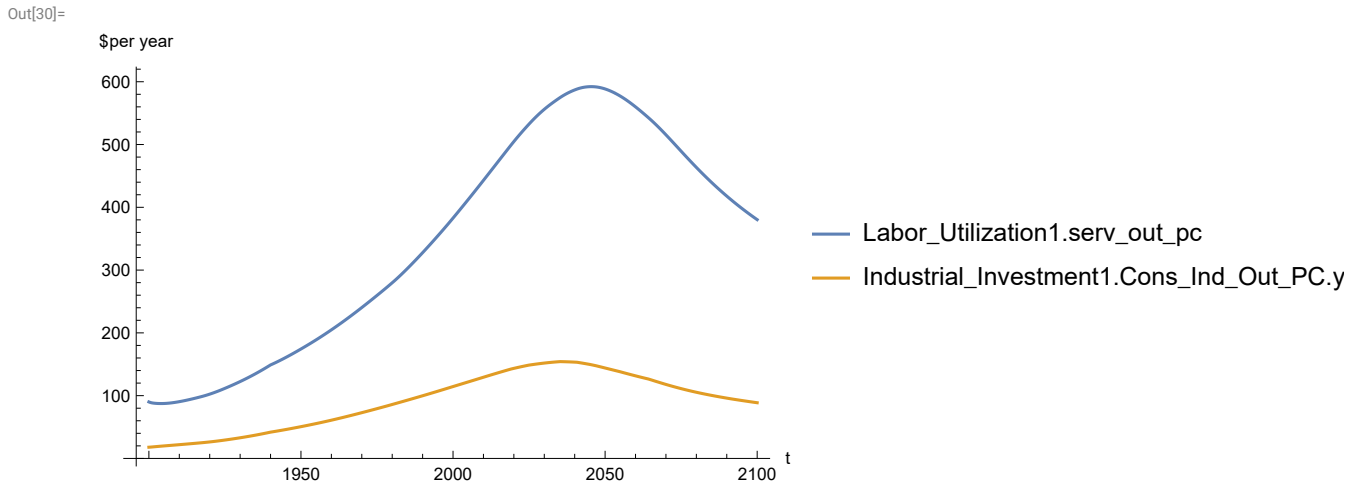
In[29]:= **SystemModelPlot[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

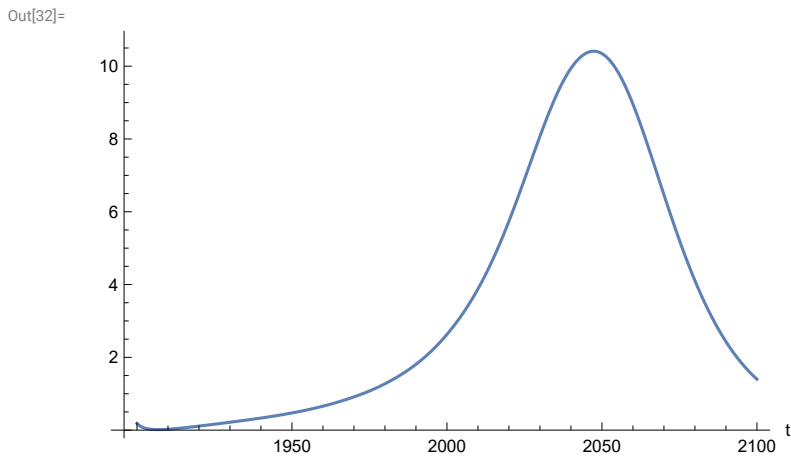


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 592.186
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



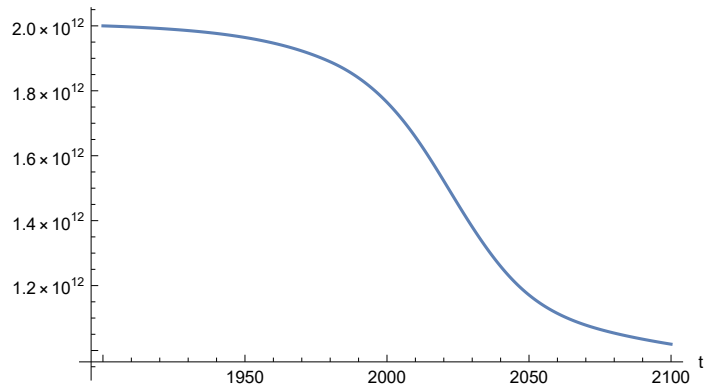
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.4113
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

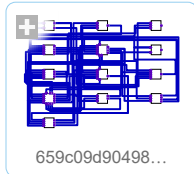


APPENDIX 67. $t_policy_year = 1970$, Benchmark Scenario 6, Experiment 67

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.


```
In[35]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[35]=
```



```
In[36]:= testsim1970 = SystemModelSimulate[newmysim1970]
```

```
Out[36]=
```

```
SystemModelSimulationData [  Model: W659c09d904984b9f8dbb008860bd1753  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of t_policy_year .

```
In[37]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
```

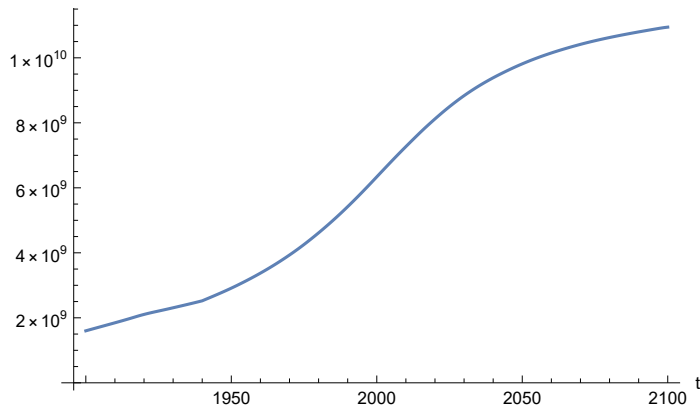
```
Out[37]=
```

```
{t_policy_year → 1970}
```

Plot the world population, people.

```
In[38]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
```

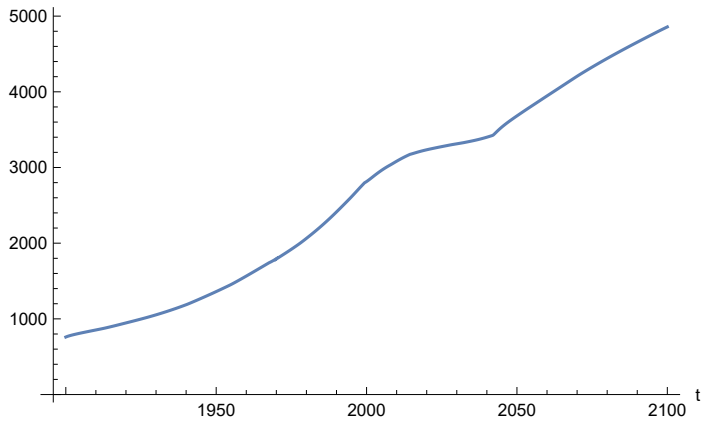
```
Out[38]=
```



Find max and min of y values.

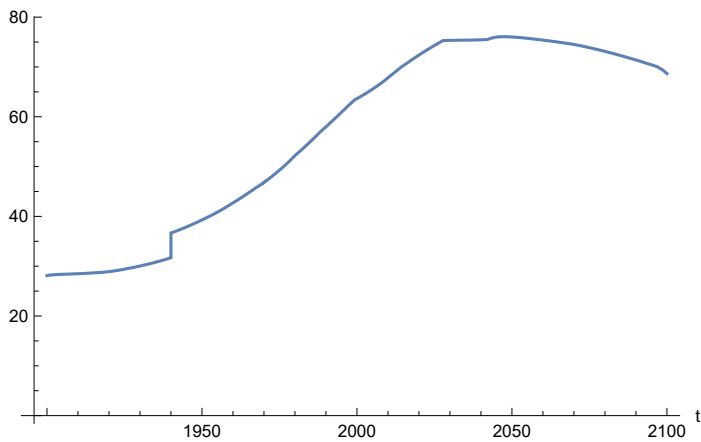
```
In[39]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $1.09439 \times 10^{10}$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[40]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
Out[40]=
```



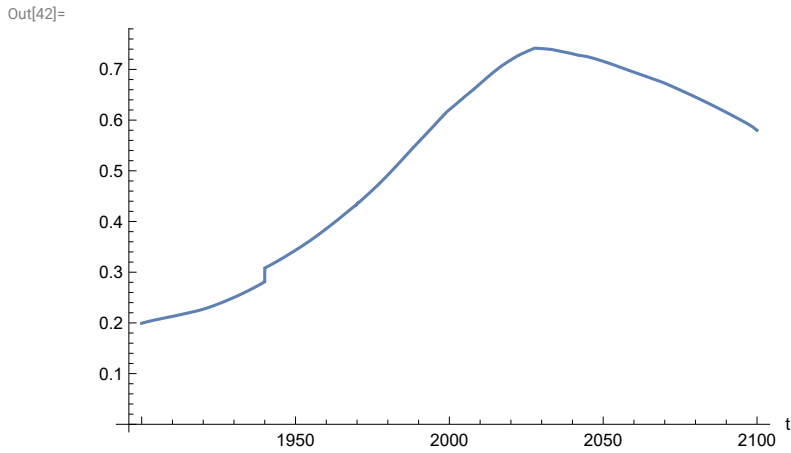
Plot life expectancy, in years.

```
In[41]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[41]=
```



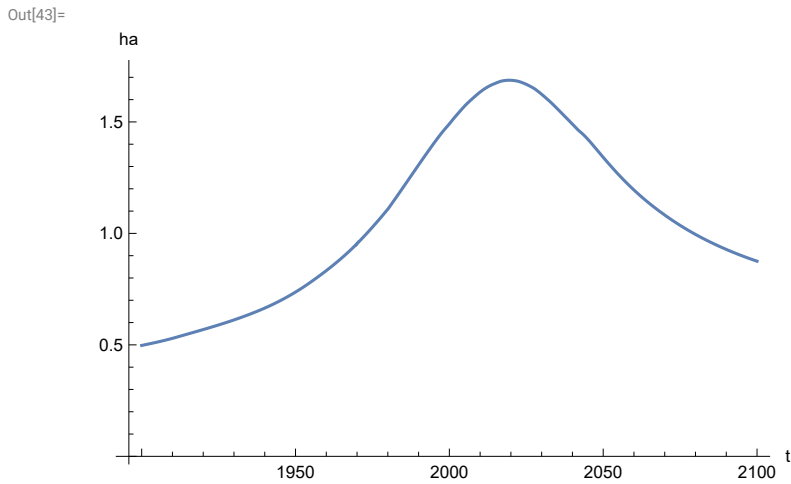
Plot the human welfare index.

```
In[42]:= SystemModelPlot[testsim1970,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



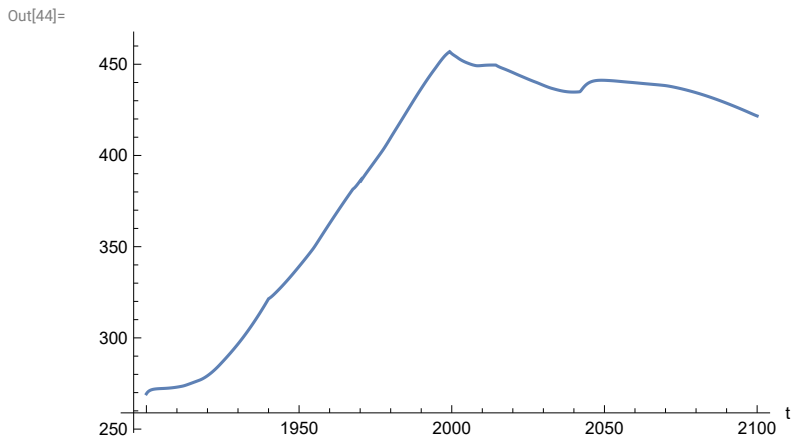
Plot the human ecological footprint, in hectares.

```
In[43]:= SystemModelPlot[testsim1970,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



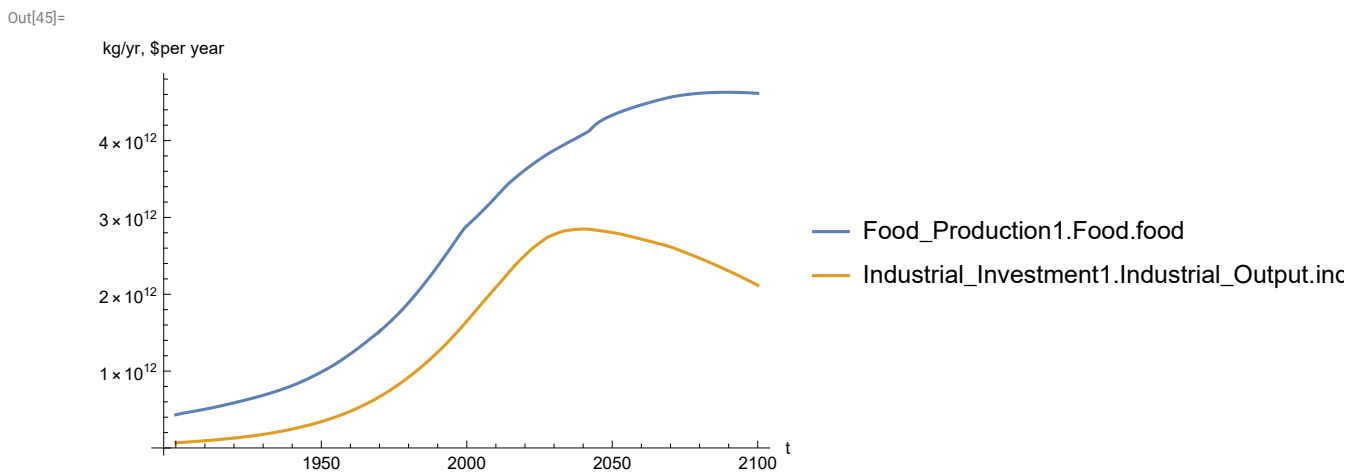
Plot per capita food production, kg/year.

In[44]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]**



Plot total food production (kg/yr) and industrial output (in dollars).

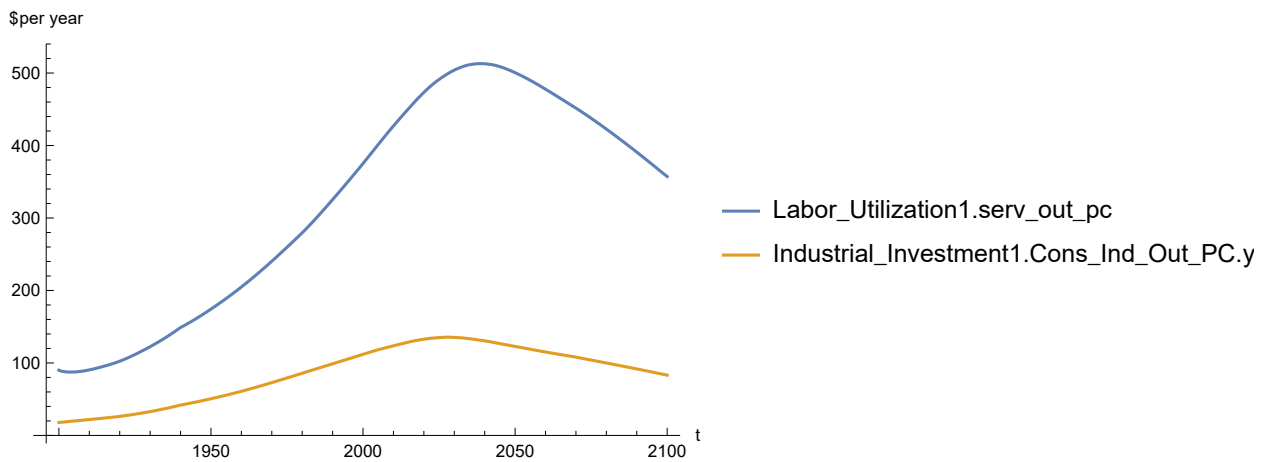
In[45]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[46]:= SystemModelPlot[testsim1970,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[46]=



Find max and min of y values.

```
In[47]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

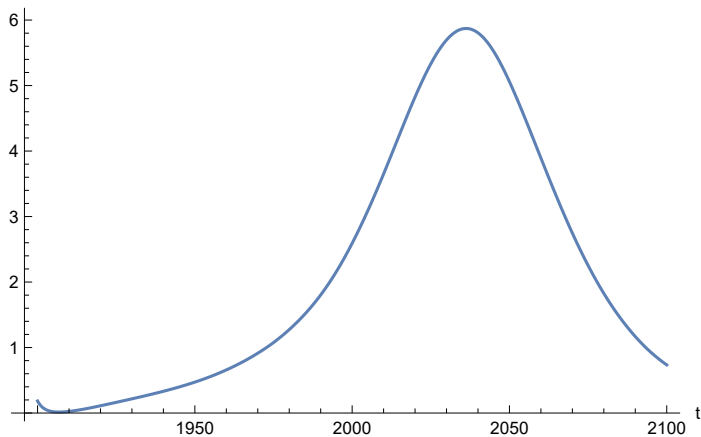
Maximum is 512.952

Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[48]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[48]=



Find max and min of y values.

```
In[49]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

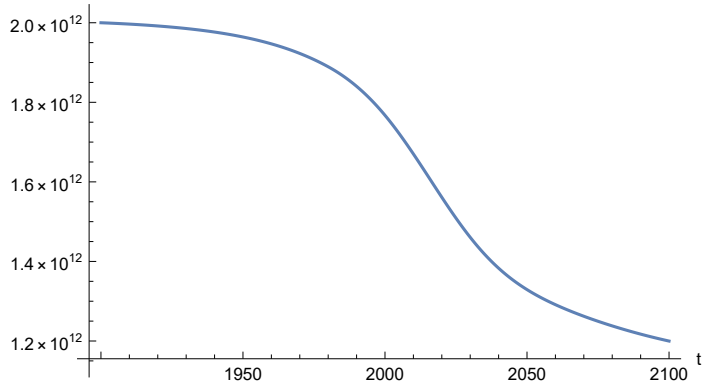
Maximum is 5.87147

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[50]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[50]=

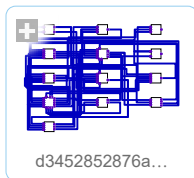


APPENDIX 68. Benchmark Scenario 6, $t_{\text{policy_year}} = 2025$. Experiment 68.

Change the value of the air pollution effect multiplier switch time $t_{\text{policy_year}}$, to calendar year 2025, and execute the resulting scenario, plotting the variables shown in Figure 2.

```
In[51]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```

```
Out[51]=
```



```
In[52]:= testsim = SystemModelSimulate[newmysim]
```

```
Out[52]=
```

```
SystemModelSimulationData [ Model: Wd3452852876a47419497383c2dae6c15  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of $t_{\text{policy_year}}$.

```
In[53]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
```

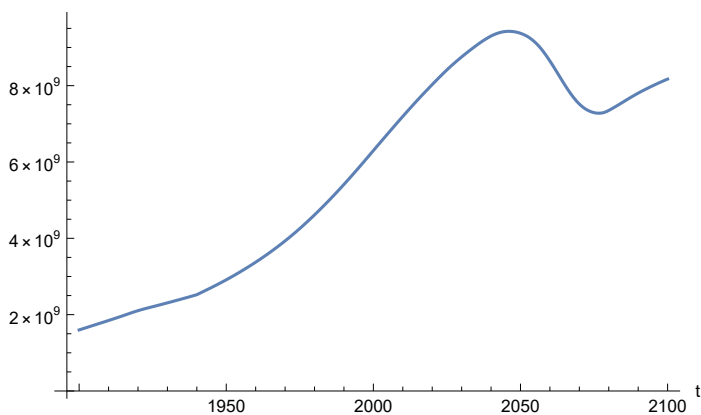
```
Out[53]=
```

```
{t_policy_year → 2025}
```

Plot the world population, people.

```
In[54]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[54]=
```

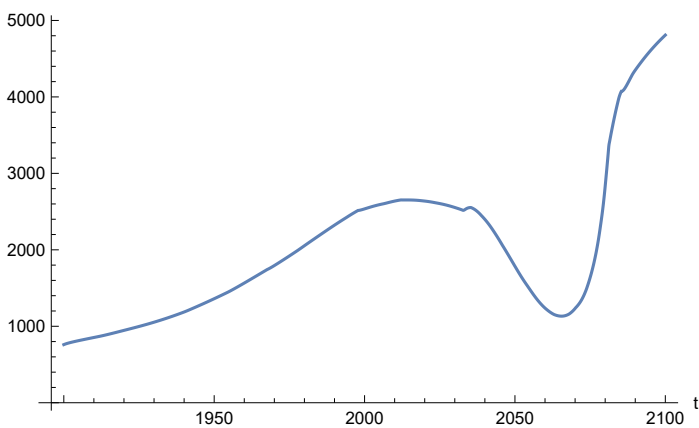


Find max and min of y values.

```
In[55]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.42337 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

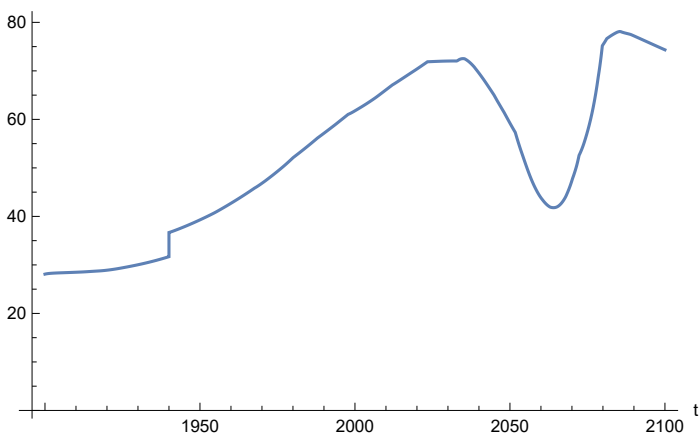
Plot land yield.

```
In[56]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[56]=
```



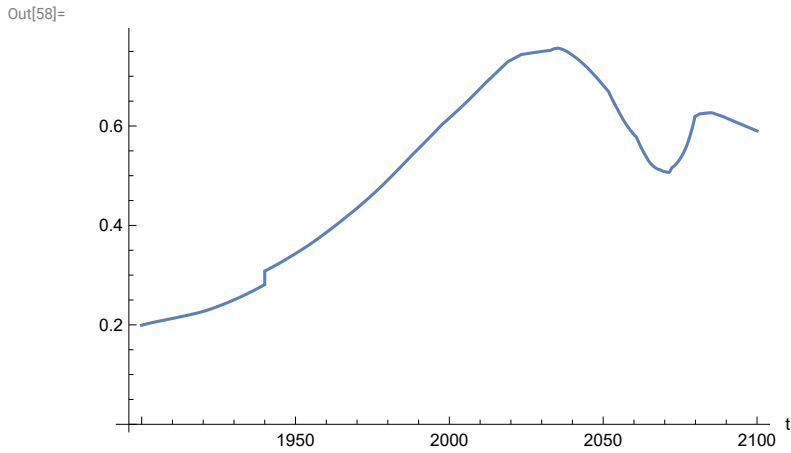
Plot life expectancy, in years.

```
In[57]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[57]=
```



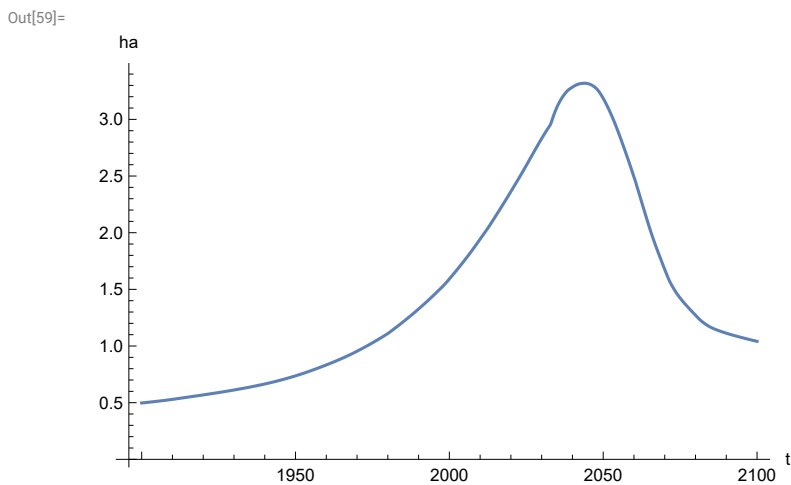
Plot the human welfare index.

```
In[58]:= SystemModelPlot[testsim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot the human ecological footprint, in hectares.

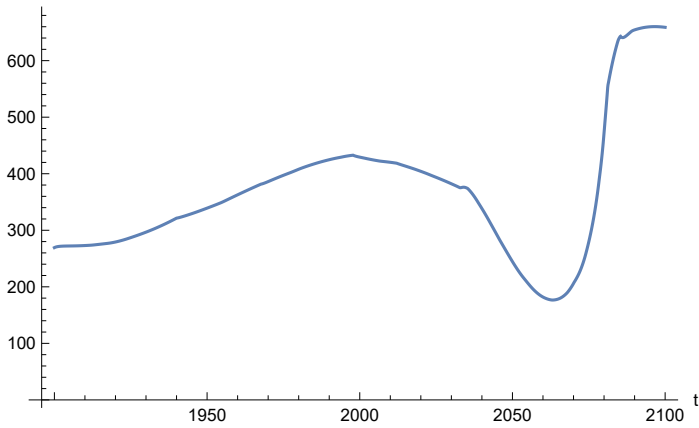
```
In[59]:= SystemModelPlot[testsim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot per capita food production, kg/year.

In[60]:= **SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]**

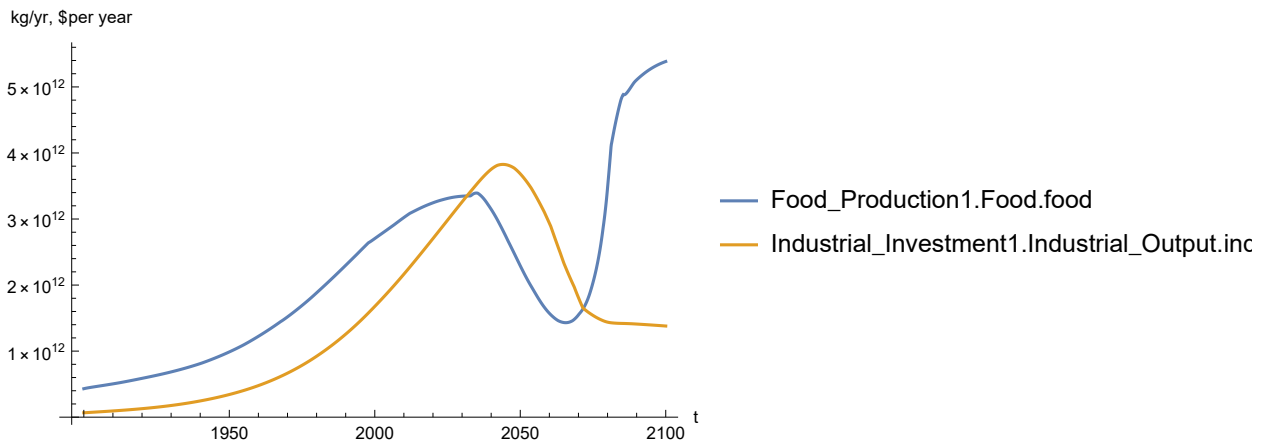
Out[60]=



Plot total food production (kg/yr) and industrial output (in dollars).

In[61]:= **SystemModelPlot[testsim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[61]=



Plot consolidated industrial output per capita (dollars/year).

```
In[62]:= SystemModelPlot[testsim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

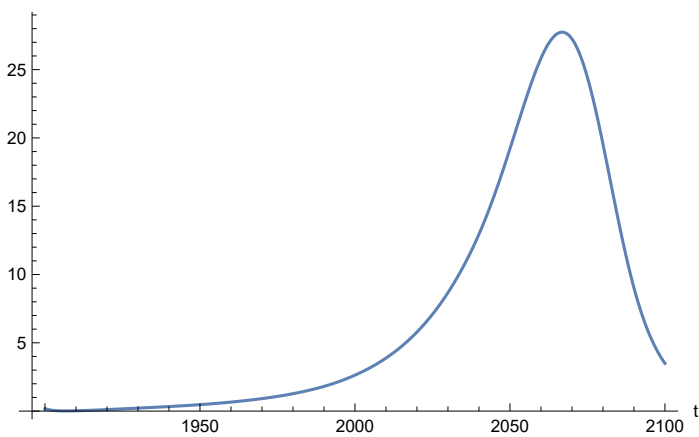


Find max and min of y values.

```
In[63]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 699.46
Minimum is 87.4451
```

Plot persistent pollution index (normalized to 1970 value).

```
In[64]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[64]=
```

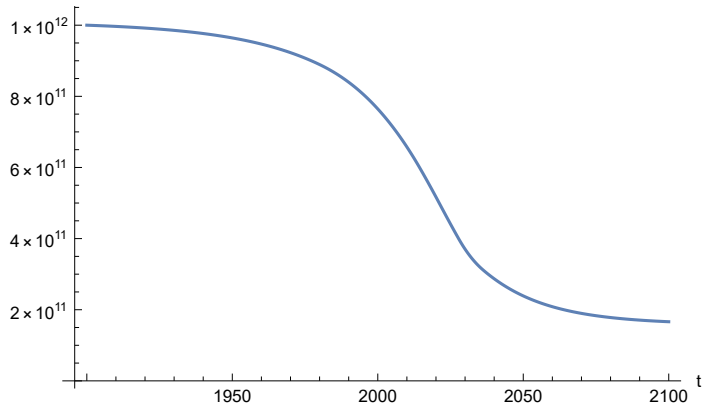


Find max and min of y values.

```
In[65]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 27.7415
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[66]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[66]=
```



APPENDIX 69. BENCHMARK SCENARIO 6, Experiment 69. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 21 July 2022/0830 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

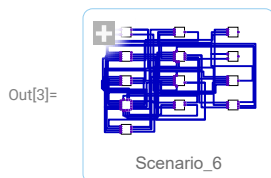
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

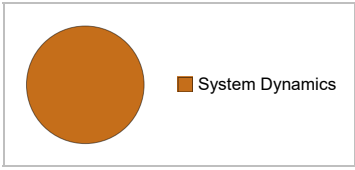
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 6

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_6"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_6
	Description	More accessible non-recoverable natural resources, pollution control, land yield enhancement, erosion pro
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background Color	True
Out[4]=	Simulation Start Year	265
	Simulation End Year	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

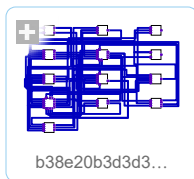
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

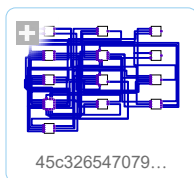
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

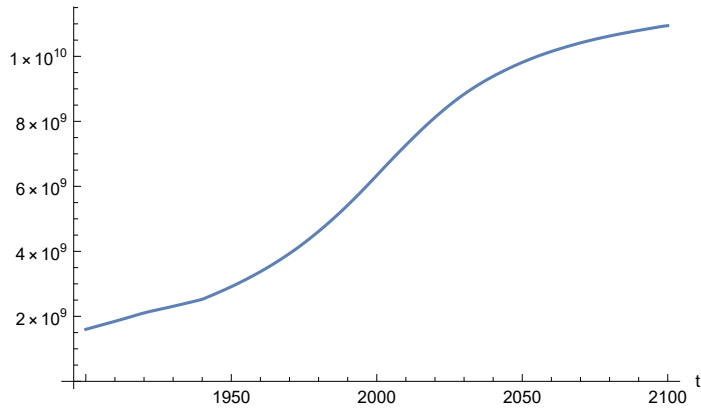
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W45c326547079453f9e264f58d1da8870  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

In[22]:= **SystemModelPlot**[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]

Out[22]=



Find max and min of population values.

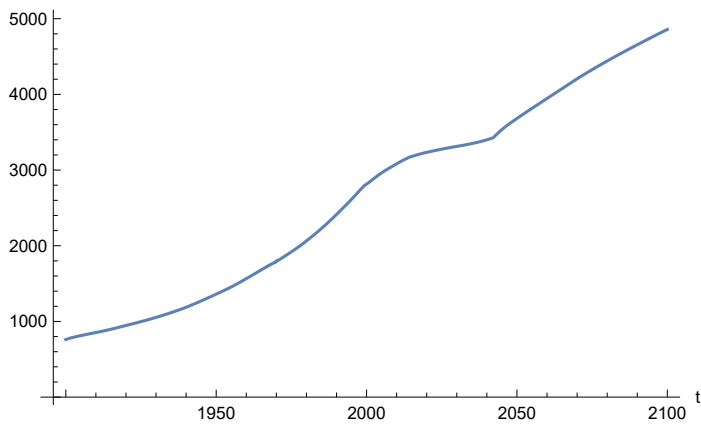
In[23]:= **MinAndMax**[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]

Maximum is 1.09439×10^{10}

Minimum is 1.6×10^9

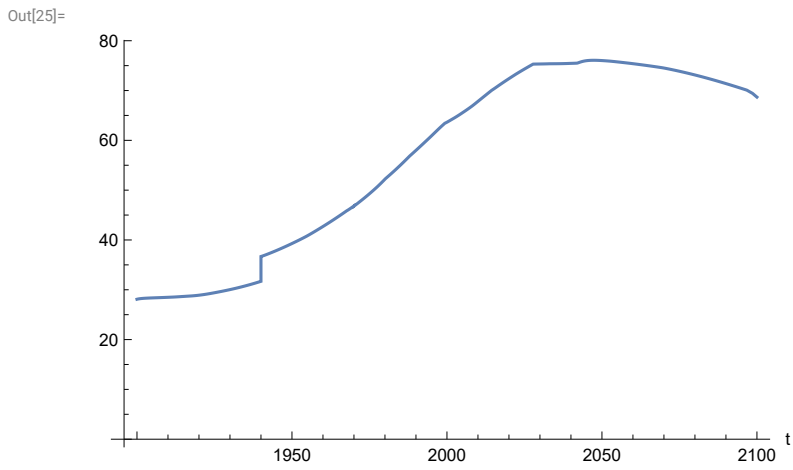
In[24]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

Out[24]=



Plot life expectancy, years.

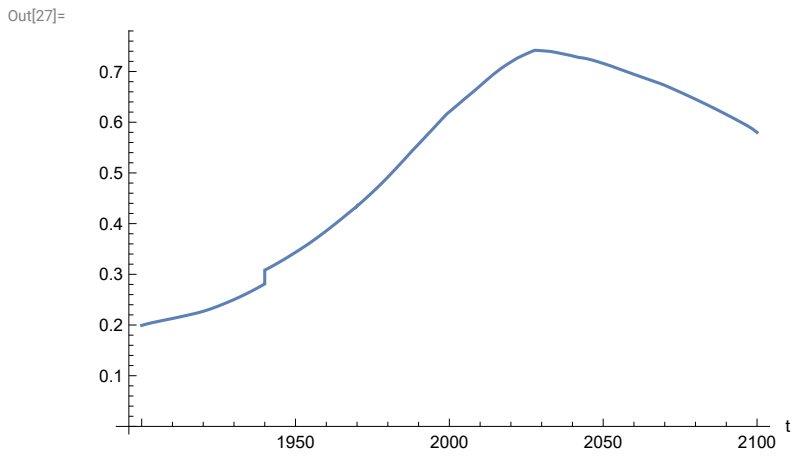
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[26]:=
```

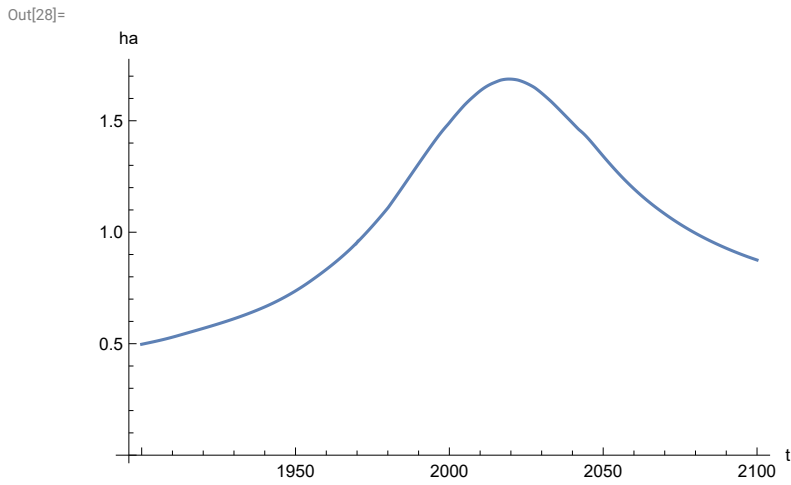
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



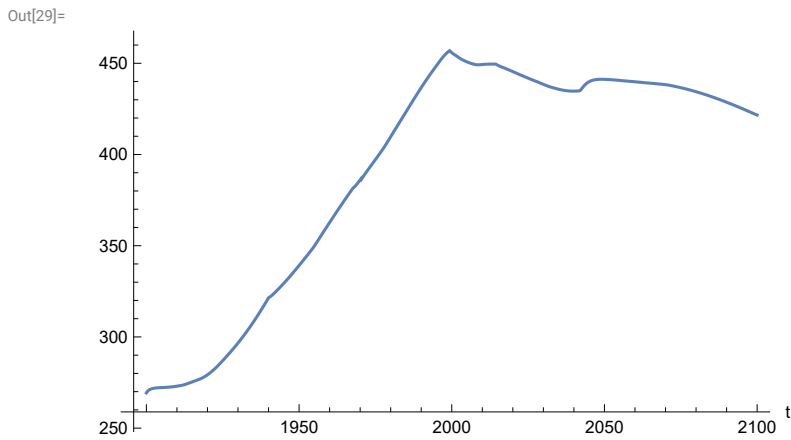
Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

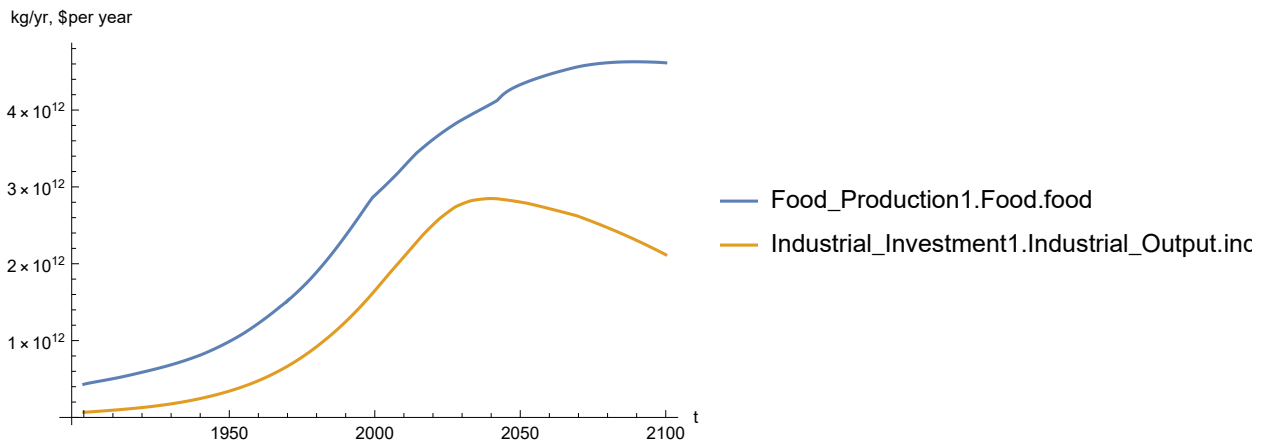
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

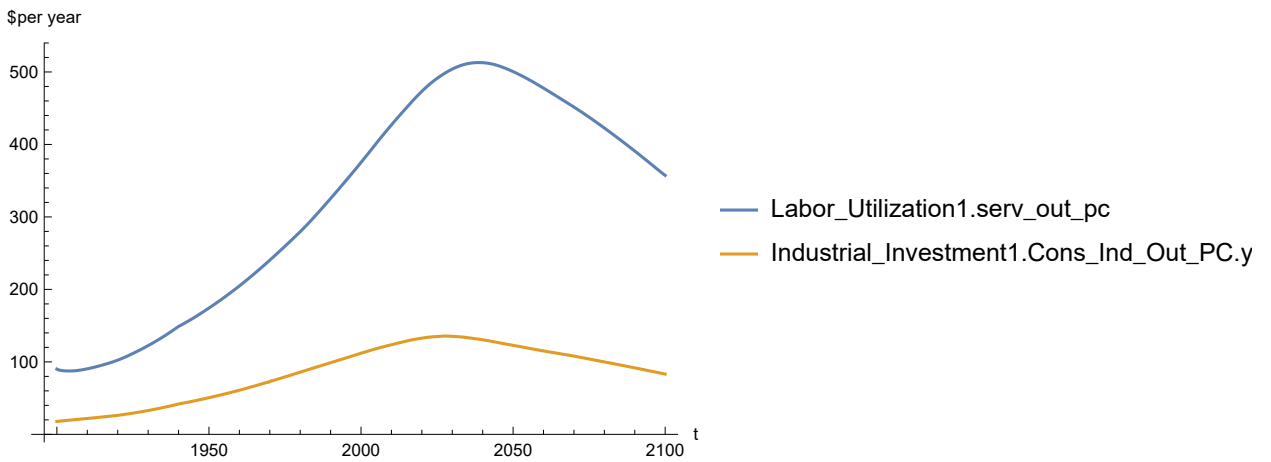
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim, {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

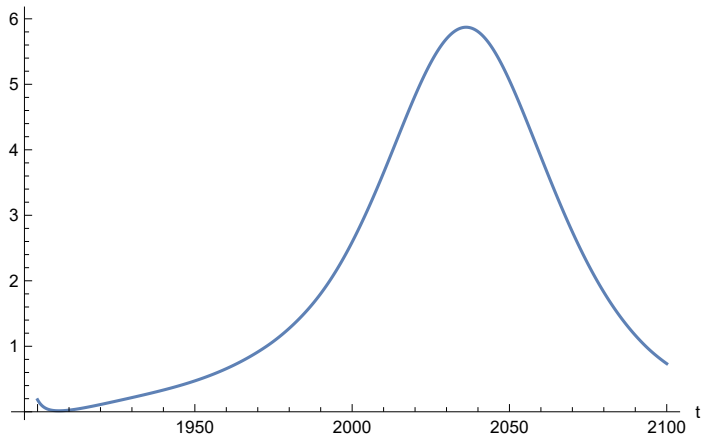
Maximum is 512.952

Minimum is 87.4451

Plot persistent pollution index.

In[33]:= **SystemModelPlot**[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]

Out[33]=



Find max and min of y values.

In[34]:= **MinAndMax**[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]

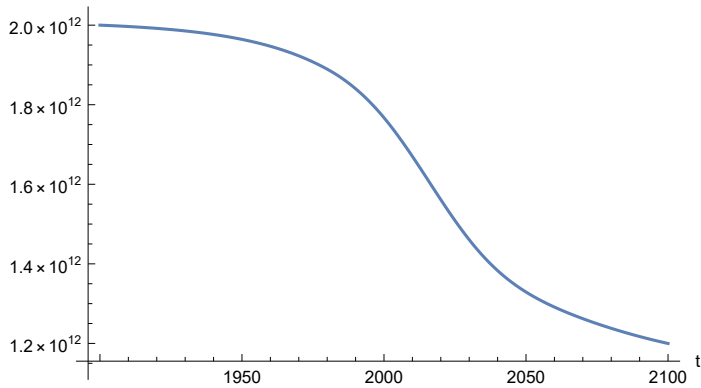
Maximum is 5.87147

Minimum is 0.0150765

Plot non-renewable resources remaining.

In[35]:= **SystemModelPlot**[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]

Out[35]=

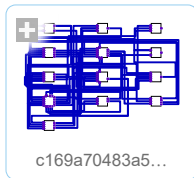


APPENDIX 70. LE/1.001, t_policy_year = 2025. Baseline Scenario 6, Experiment 70.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure default _Serv_2.y_vals

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

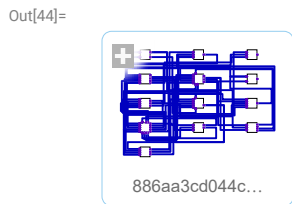
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```



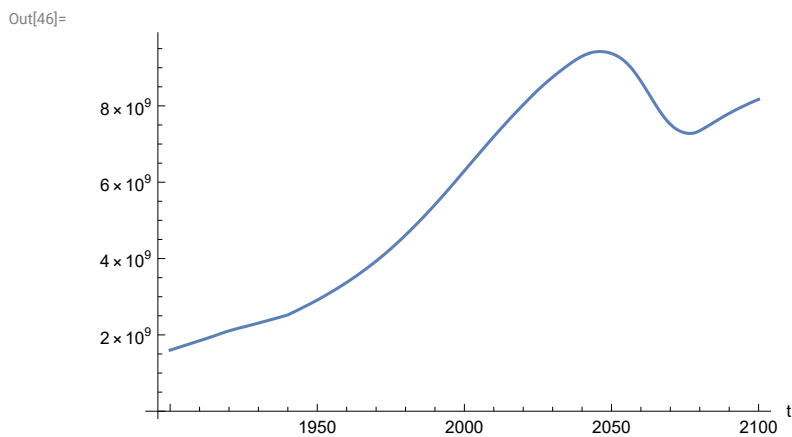
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W886aa3cd044c41abb667b1d0728b010b
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

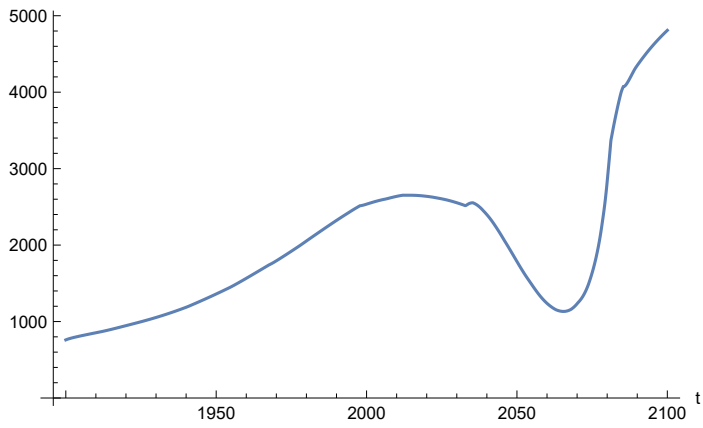
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 9.42337×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

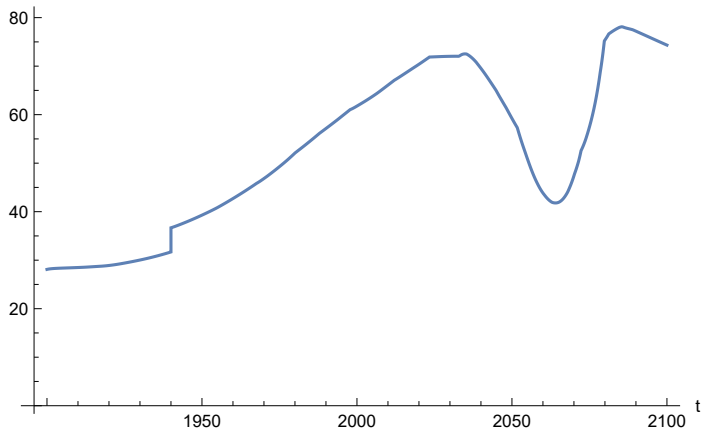
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

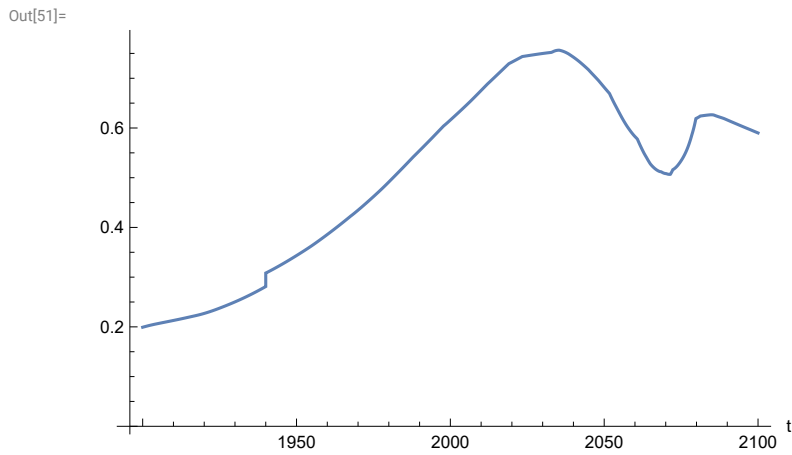
Out[49]=



In[50]=

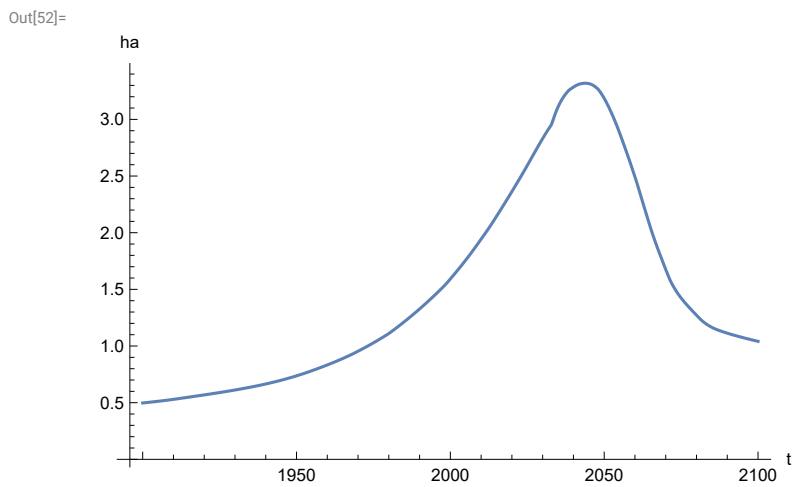
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

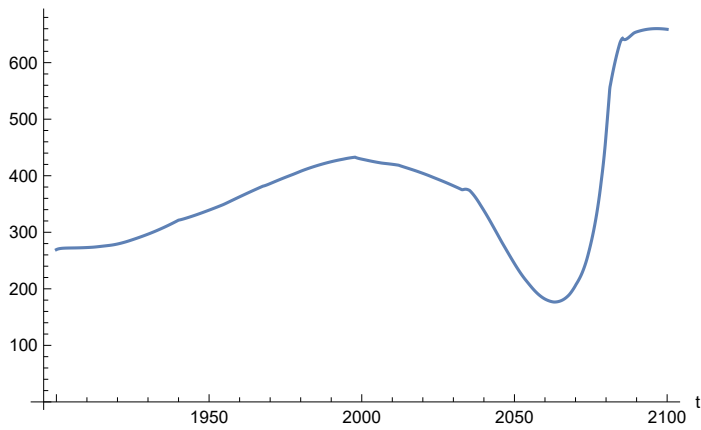
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

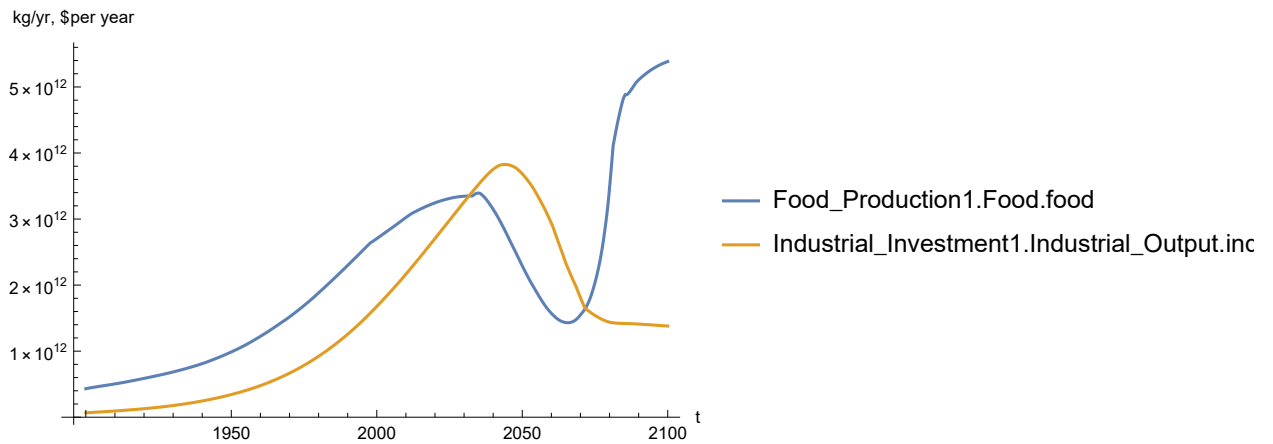
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

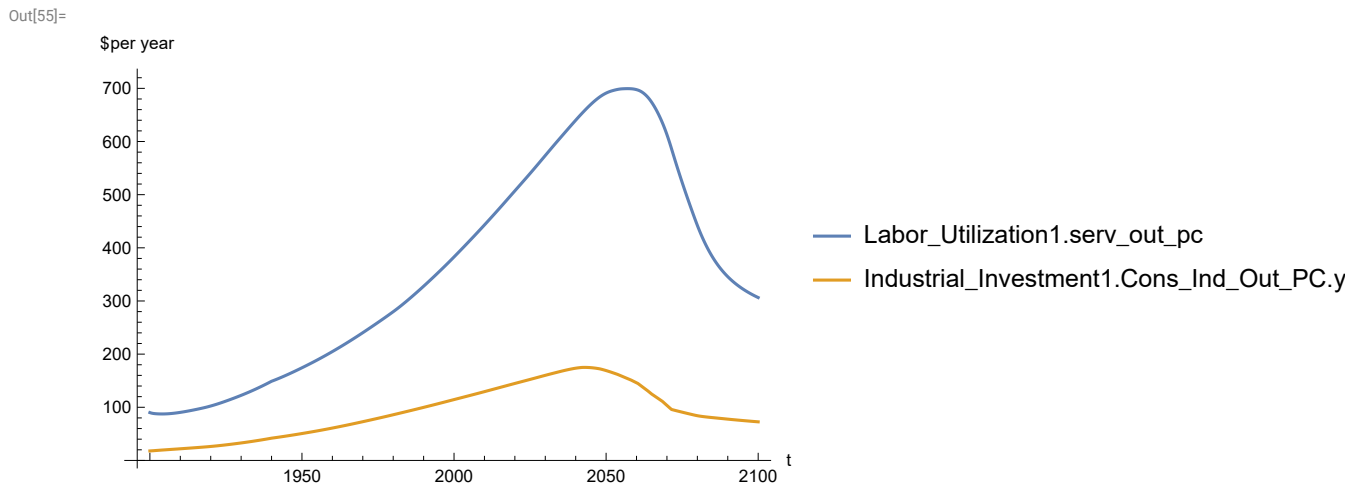
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

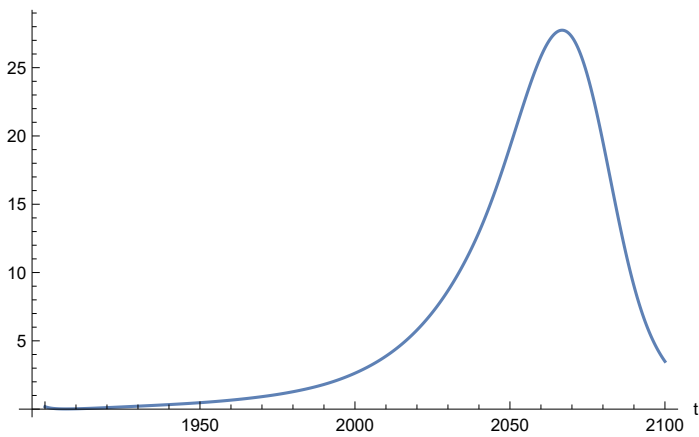


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 699.46
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



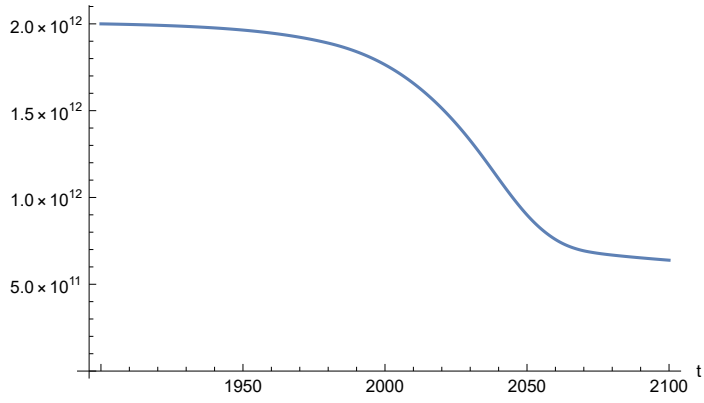
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 27.7415
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

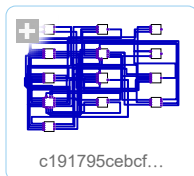


APPENDIX 71. LE/1.01, t_policy_year = 1970. Baseline Scenario 6, Experiment 71.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

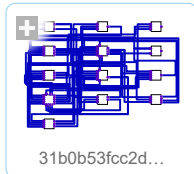
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}}>]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

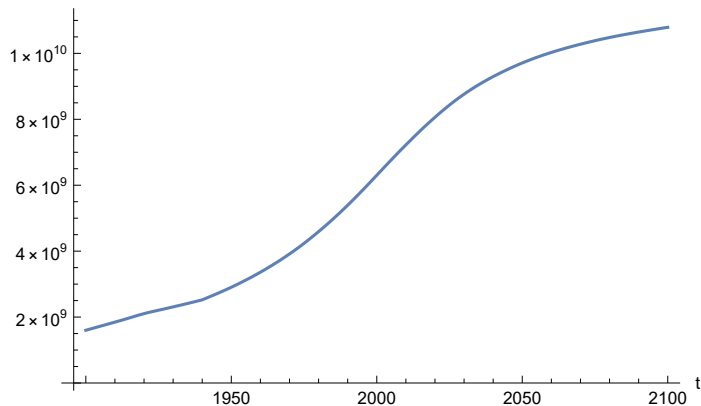
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W31b0b53fcc2d493d4fe322651d5c0880  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

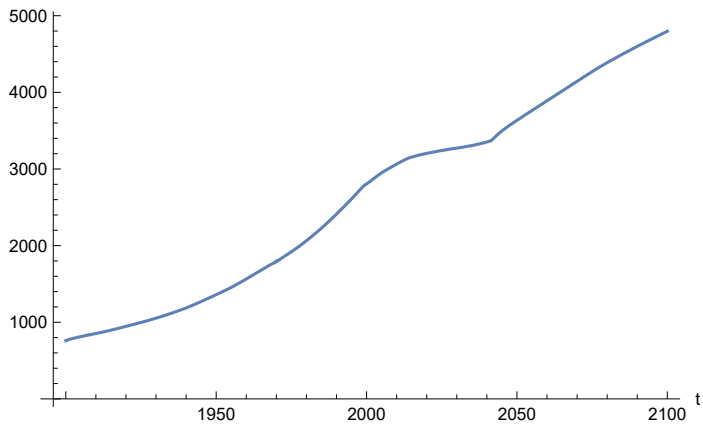
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $1.07899 \times 10^{10}$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

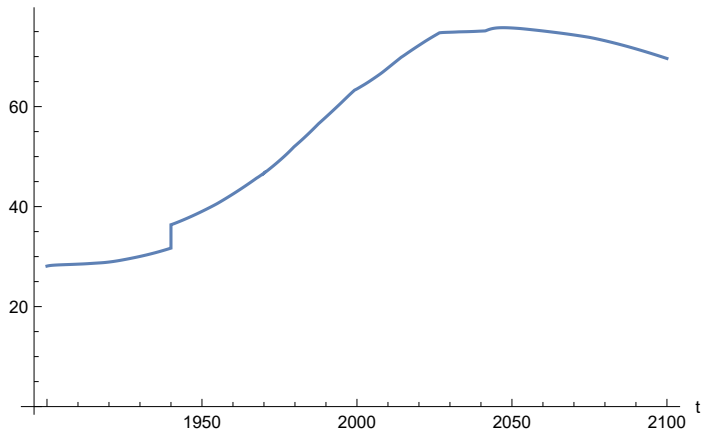
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

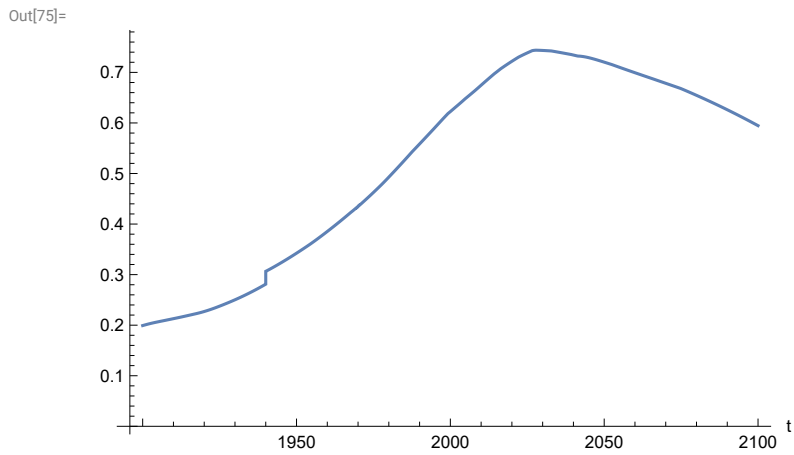
Out[73]=



In[74]:=

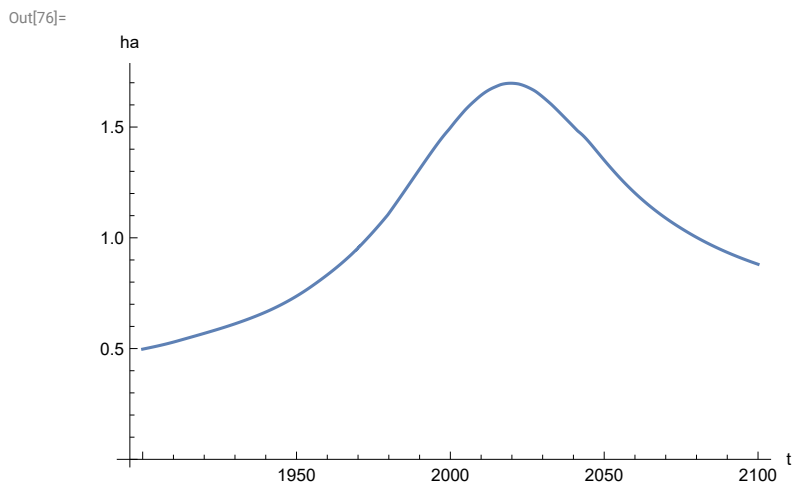
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



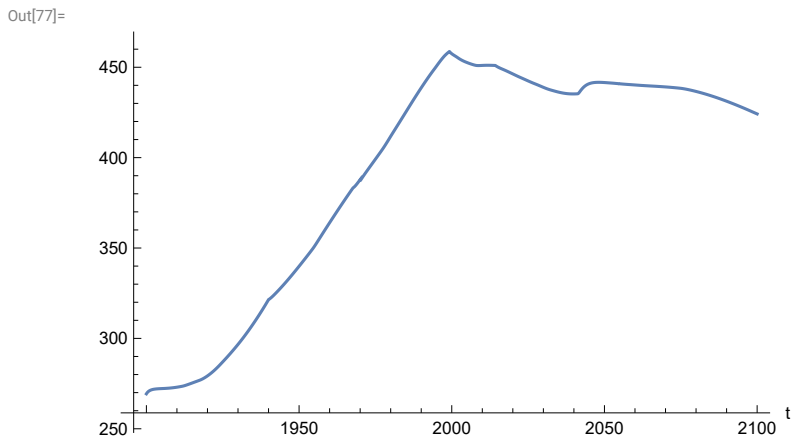
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



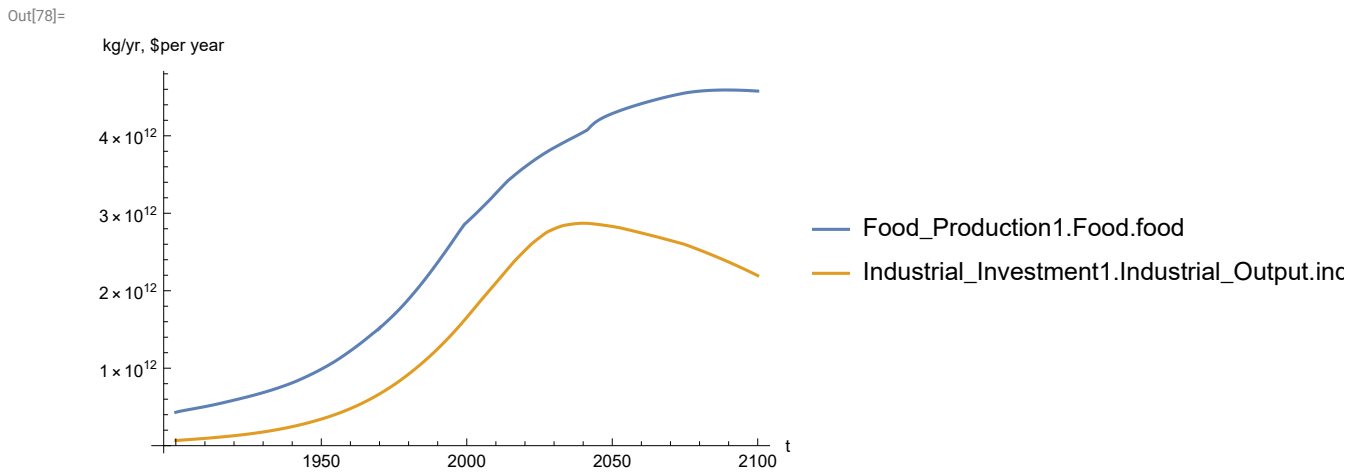
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



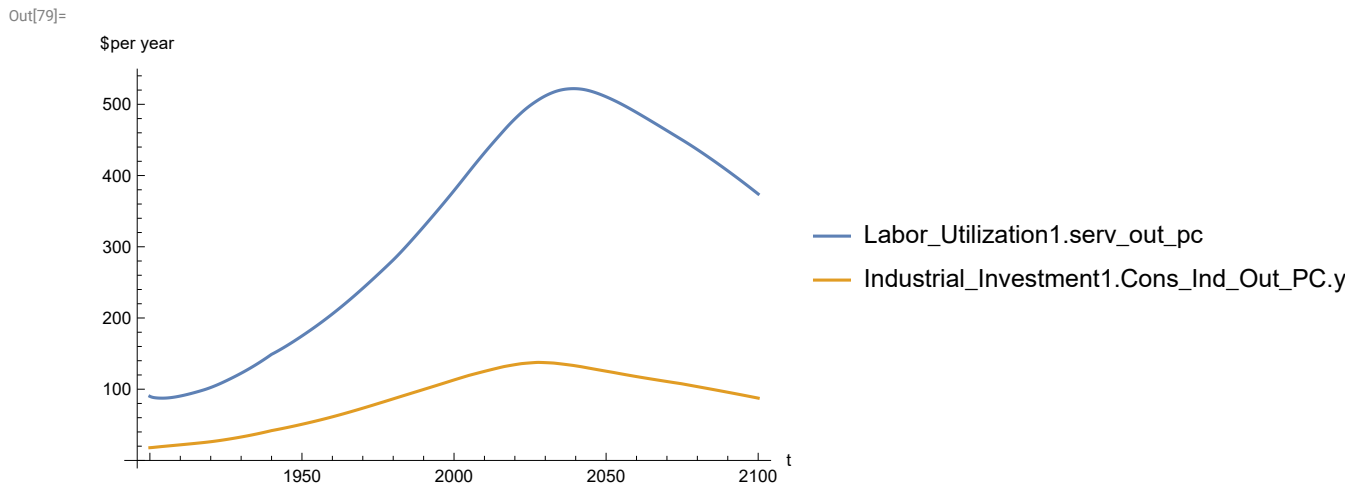
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

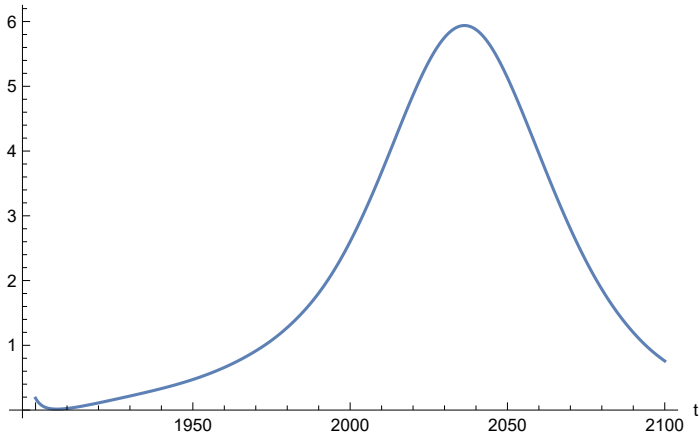


Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 522.008
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[81]=
```



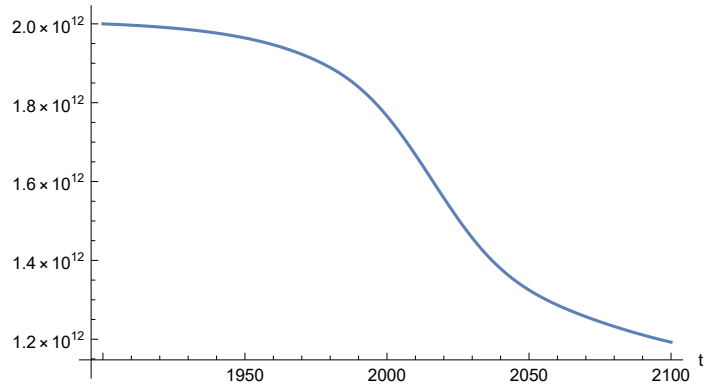
Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 5.93873
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

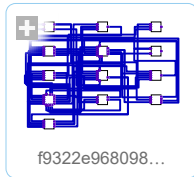
Out[83]=



APPENDIX 72. Baseline Scenario 6, Experiment 72. $LE = LE/1.01$, $t_policy_year = 2025$.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

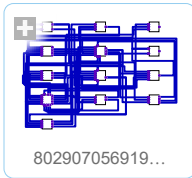
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```


Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



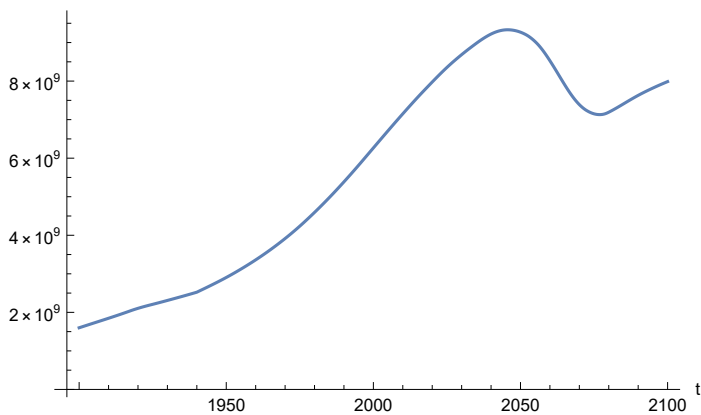
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

```
SystemModelSimulationData [  Model: W80290705691946788e27c1d9d50bf169  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

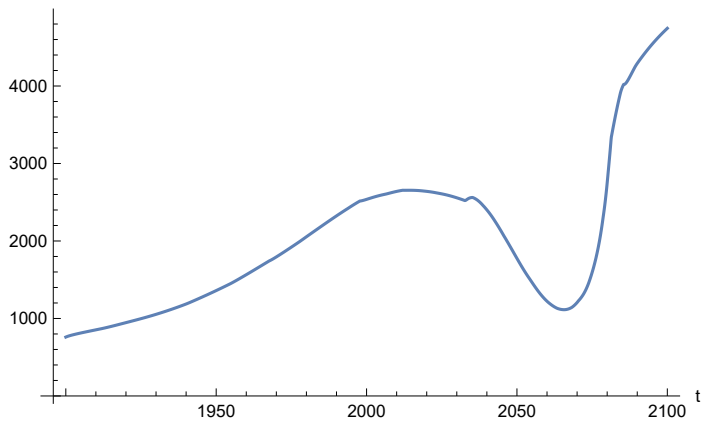


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.33152 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

In[96]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

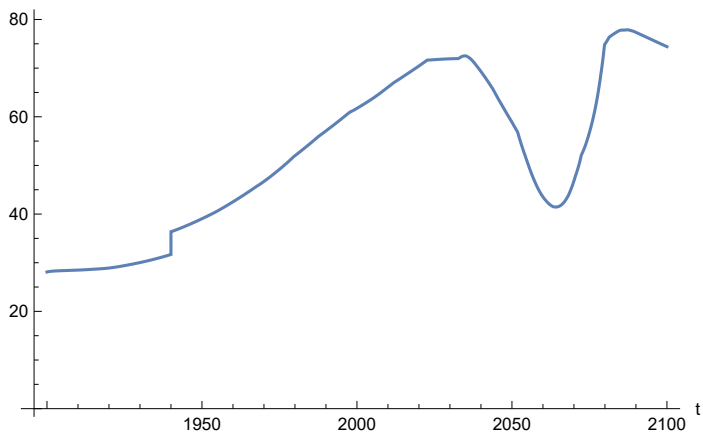
Out[96]=



Plot life expectancy, years.

In[97]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

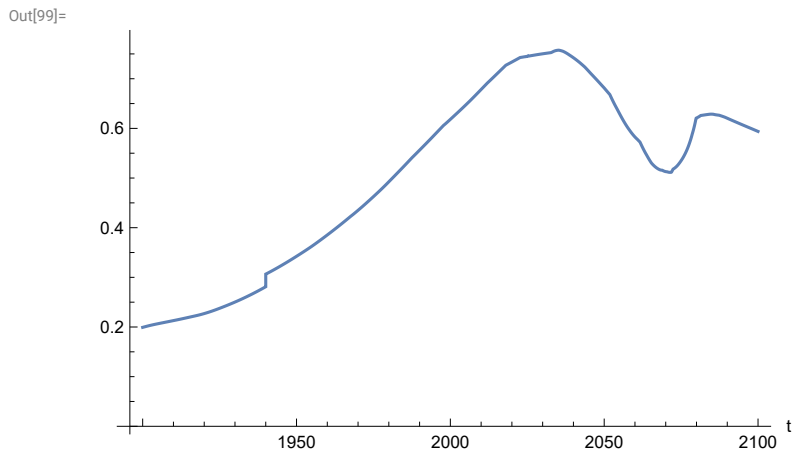
Out[97]=



In[98]:=

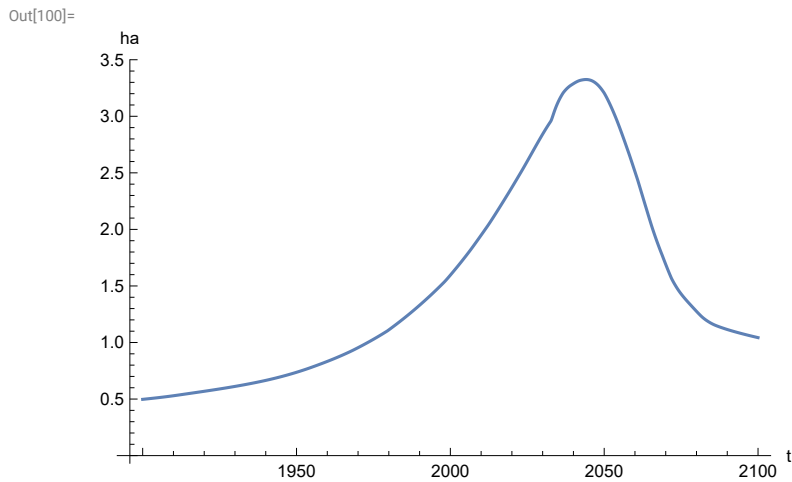
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

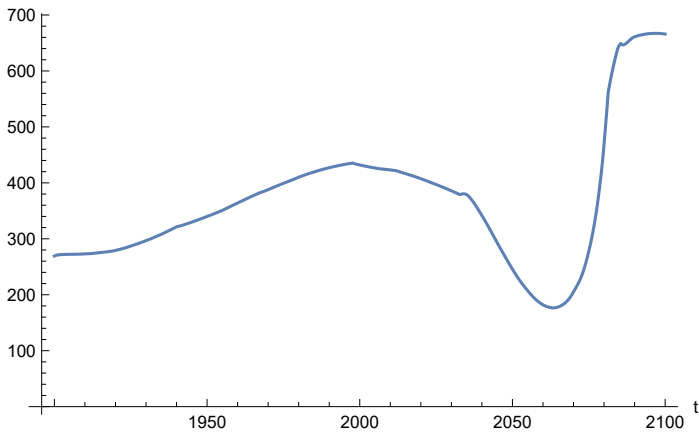


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

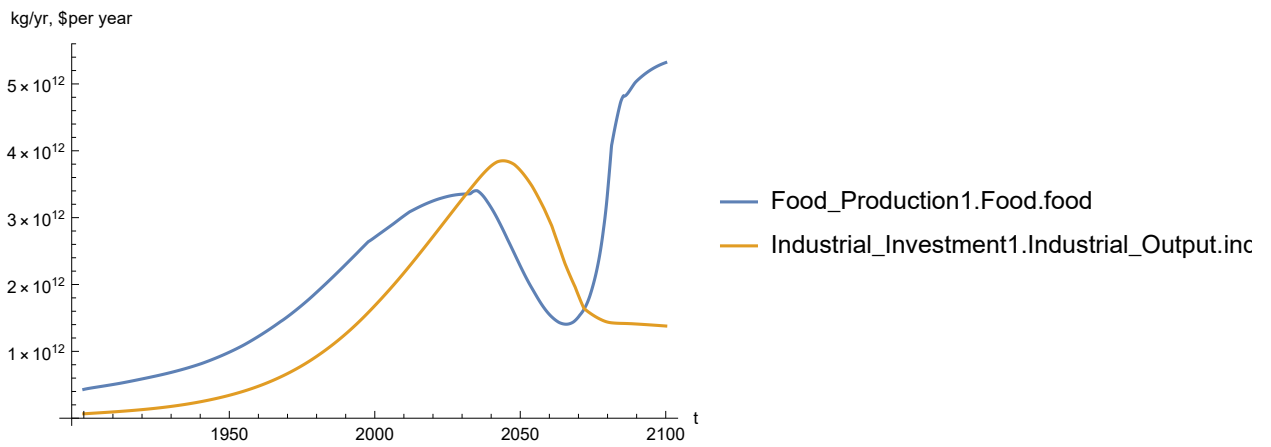


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

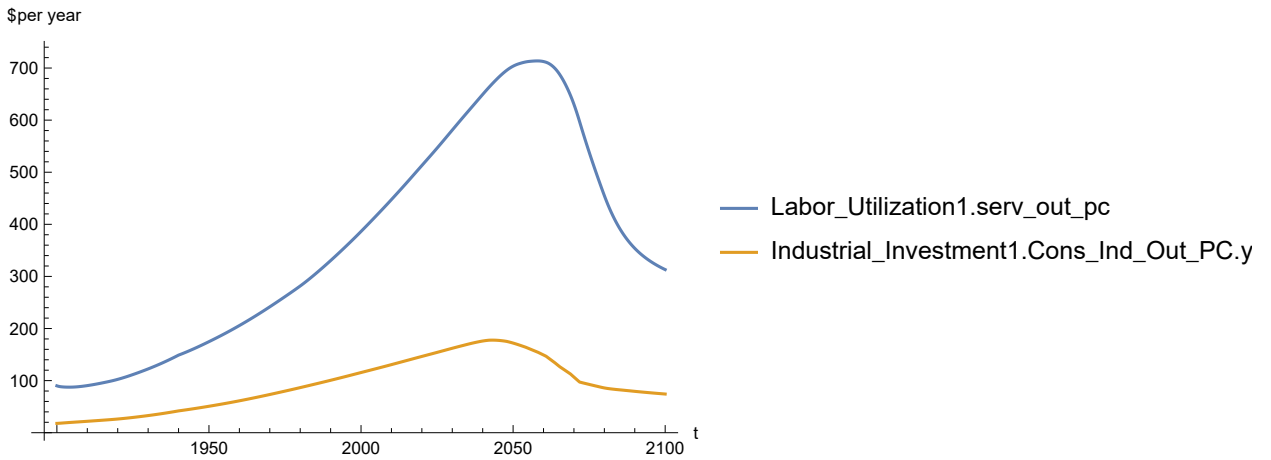


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

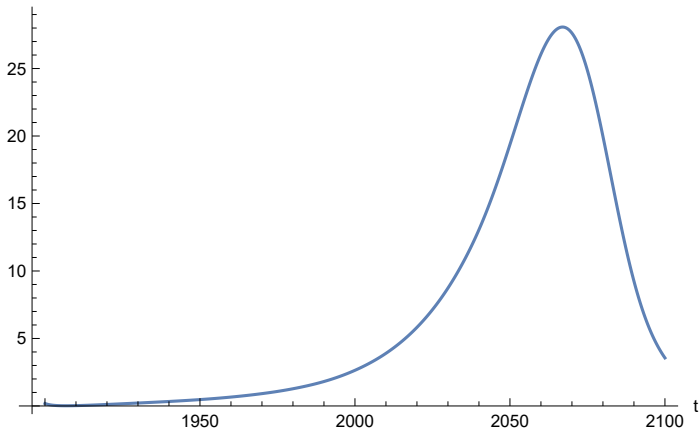
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 713.655
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 28.0737

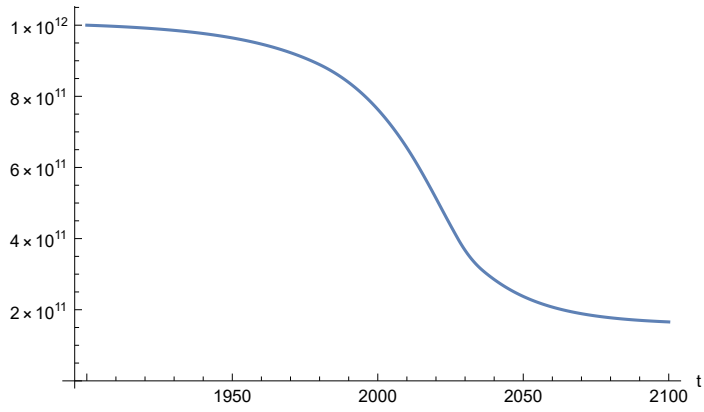
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 73. BENCHMARK SCENARIO 6, Experiment 73. $LE = LE/1.03$, $t_{policy_year} = 1970$.
Last modified: 25 July 2022/1030 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

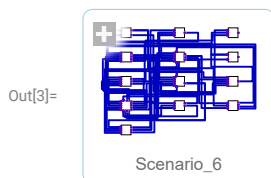
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

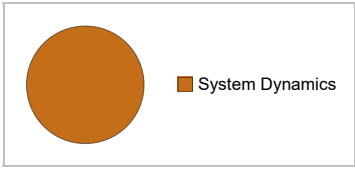
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 6.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_6"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_6
	Description	More accessible non-recoverable natural resources, pollution control, land yield enhancement, erosion pro
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background	True
Out[4]=	Simulation Length	265
	Simulation Length	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

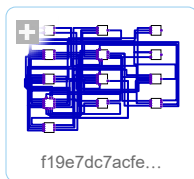
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

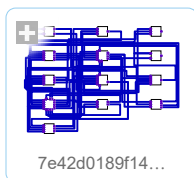
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

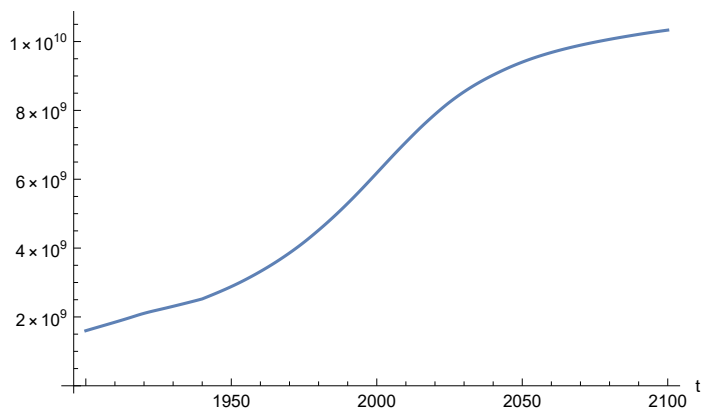
```
Out[21]=
```

```
SystemModelSimulationData [
   Model: W7e42d0189f14429d84c522bb1347239b
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

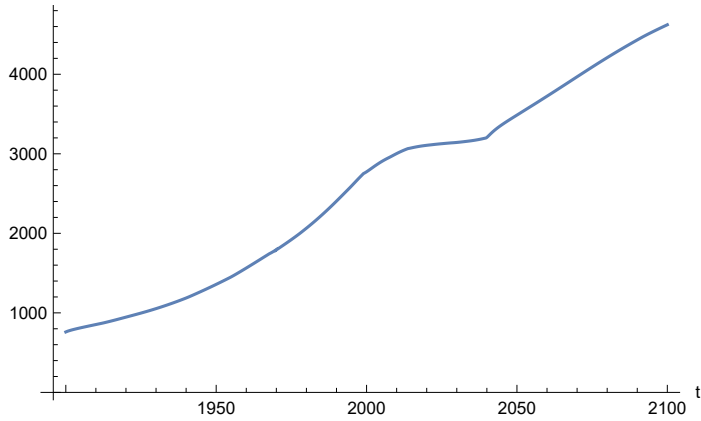
```
Out[22]=
```



Find max and min of population values.

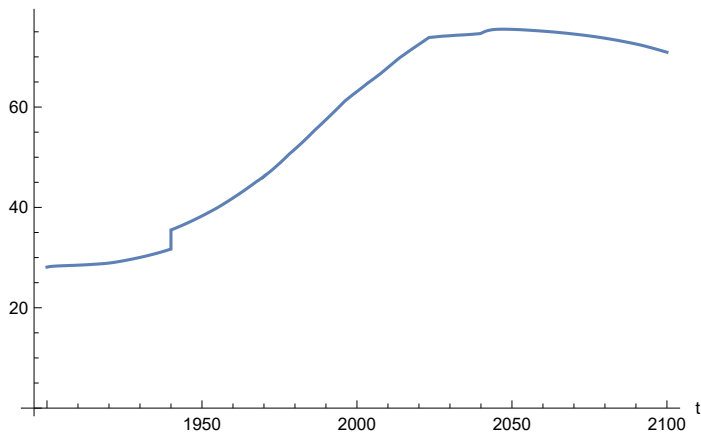
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $1.03322 \times 10^{10}$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

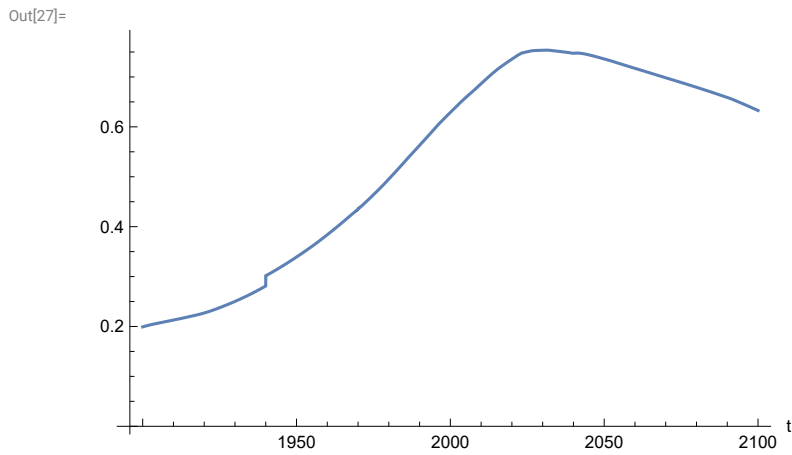
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```



```
In[26]:=
```

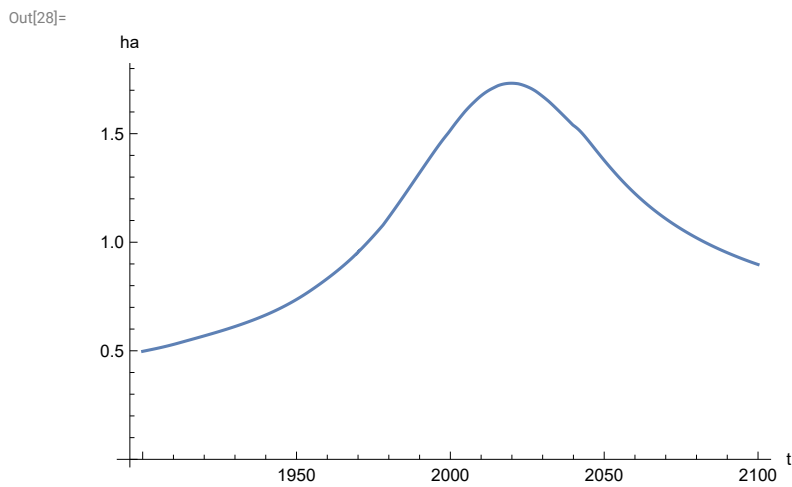
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

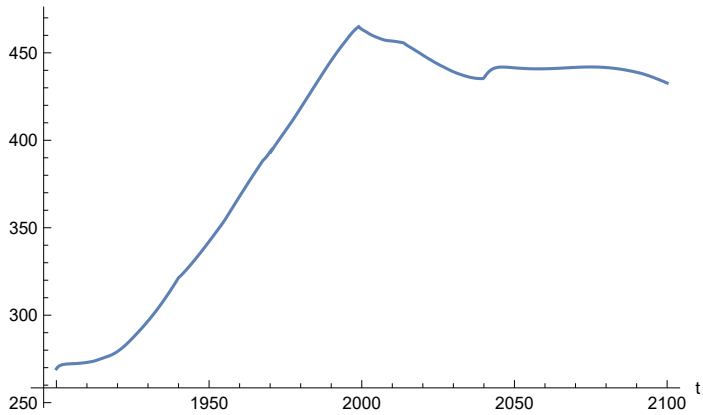
```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

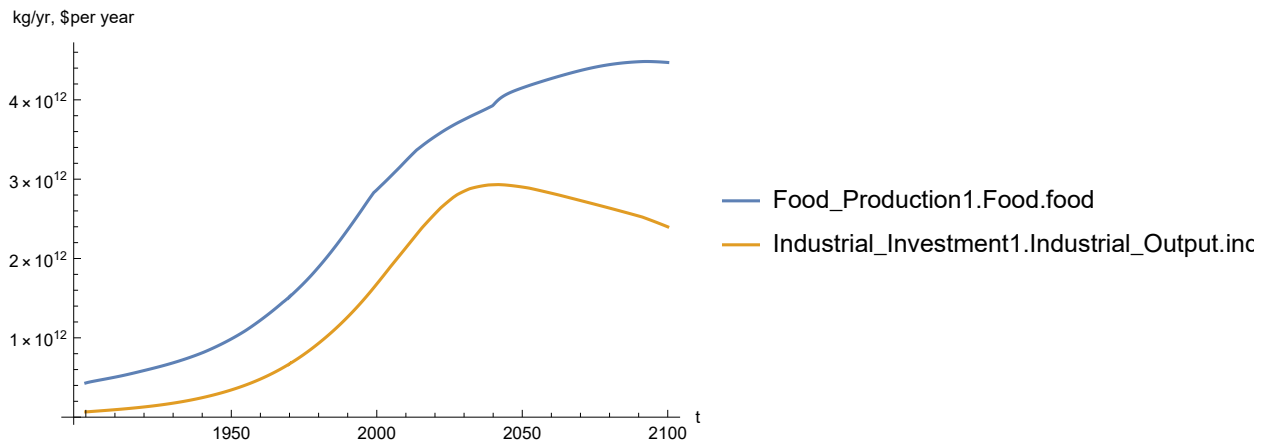
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

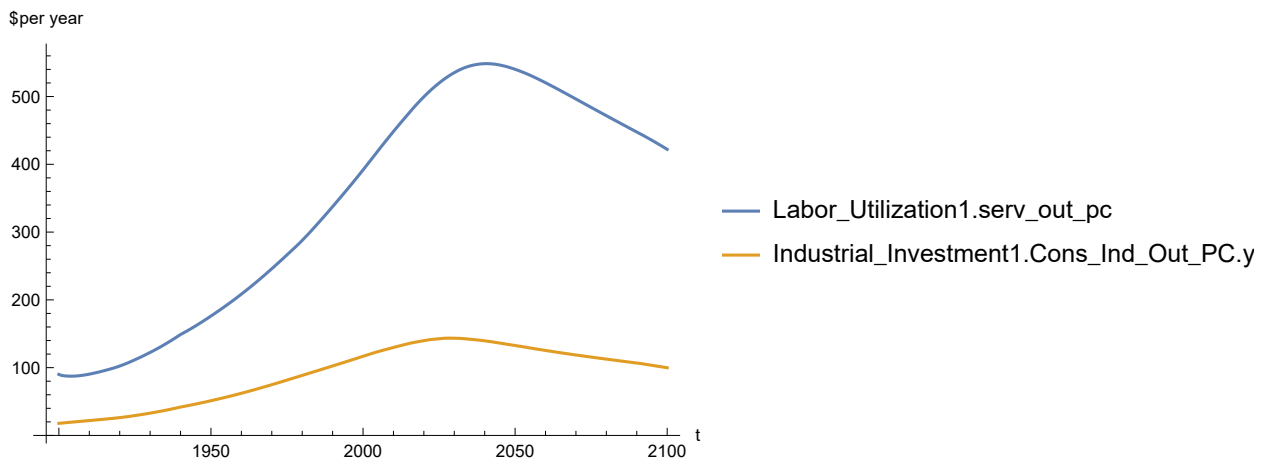
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

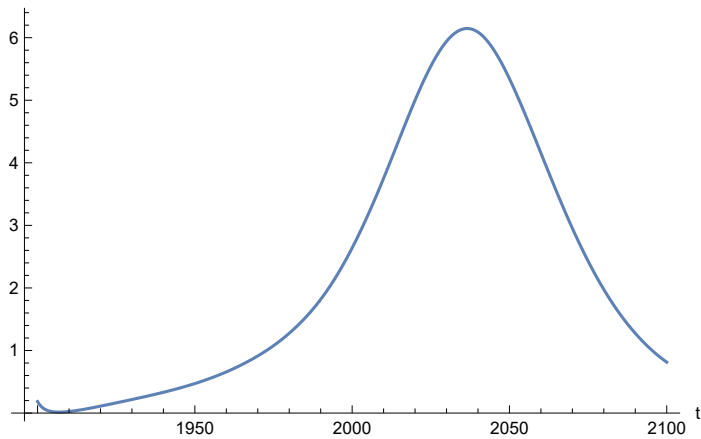
Maximum is 548.509

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

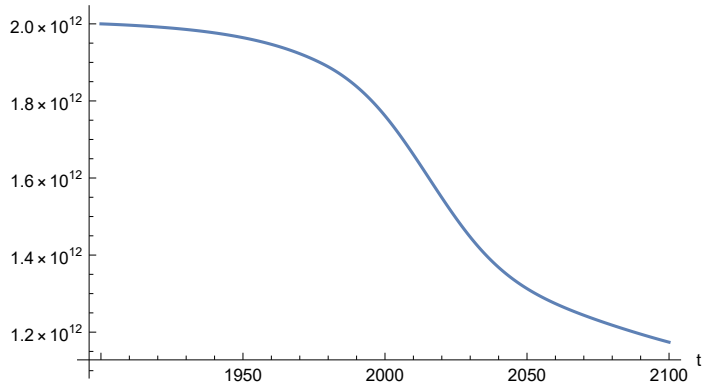
Maximum is 6.14622

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

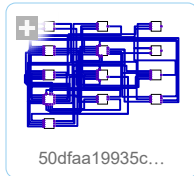


APPENDIX 74. LE/1.03, t_policy_year = 2025. Baseline Scenario 6, Experiment 74.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

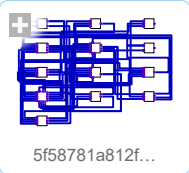
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

Out[44]=  5f58781a812f...

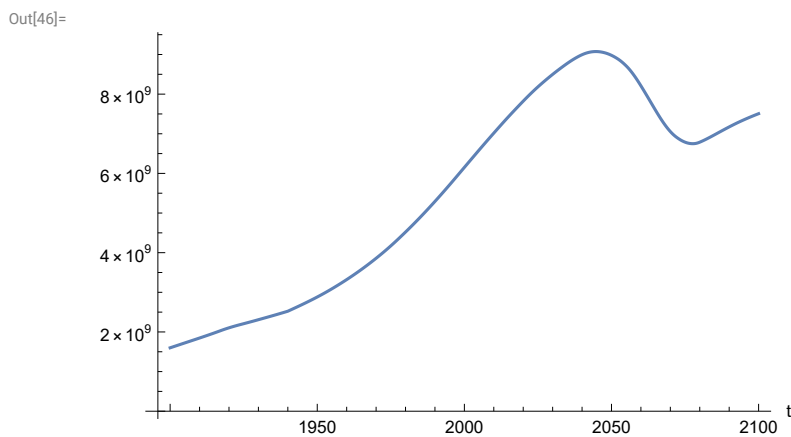
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W5f58781a812f47e7ac2749f14fdfa574
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

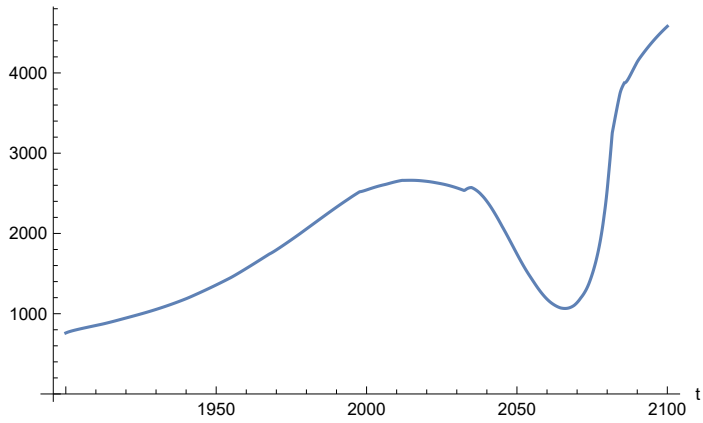
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 9.07433×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

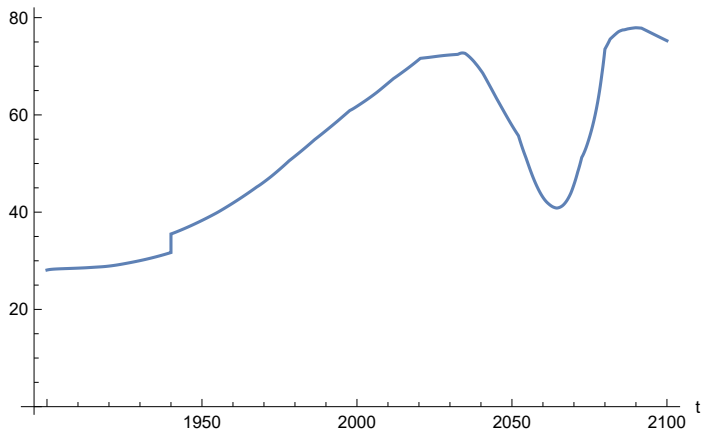
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

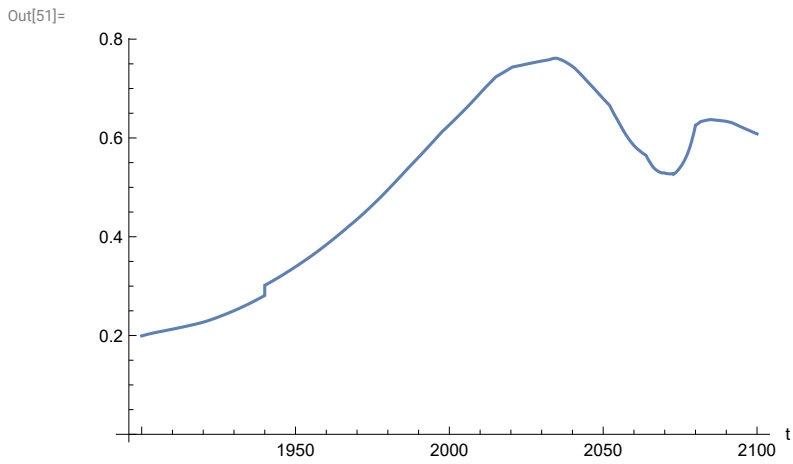
Out[49]=



In[50]:=

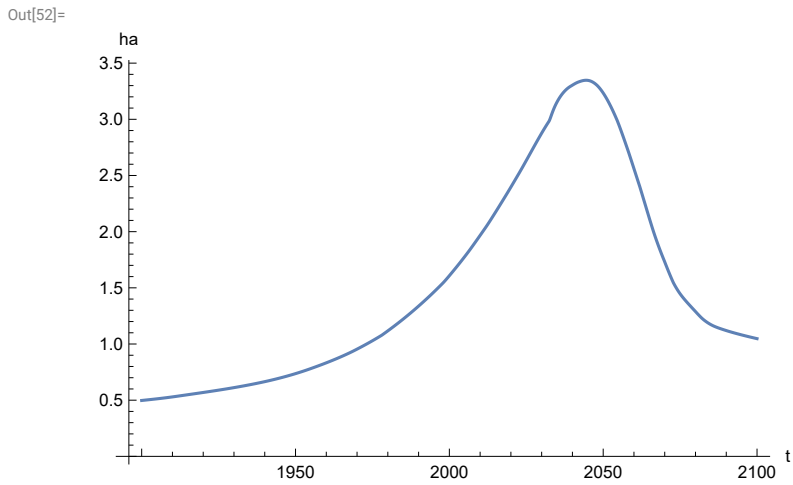
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



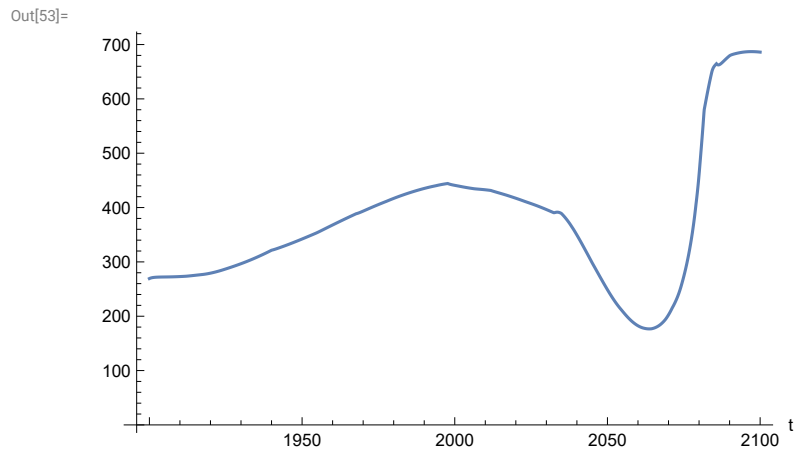
Plot per capita ecological footprint, hectares.

```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



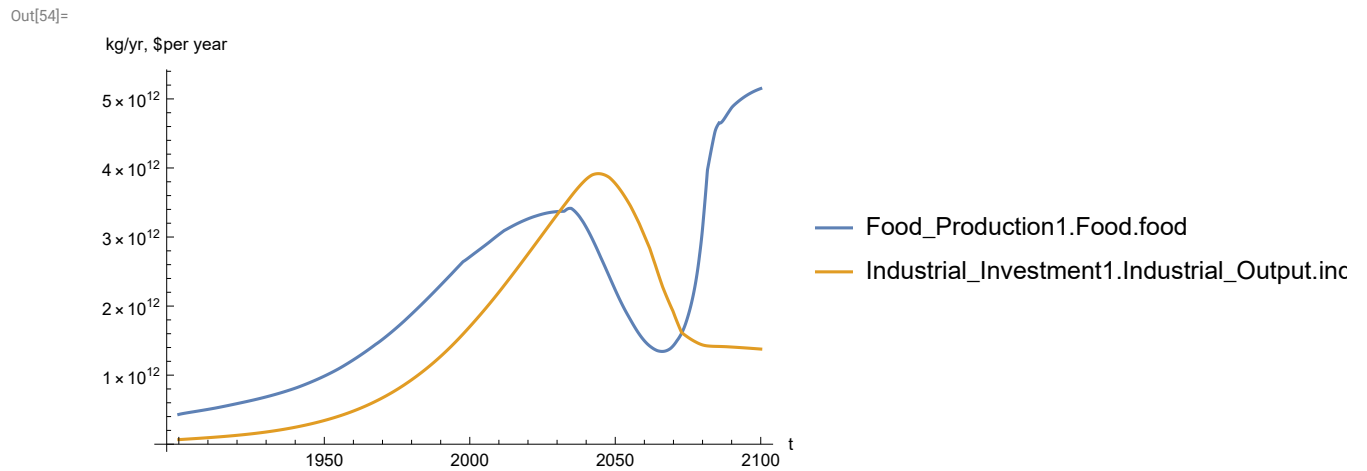
Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]



Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

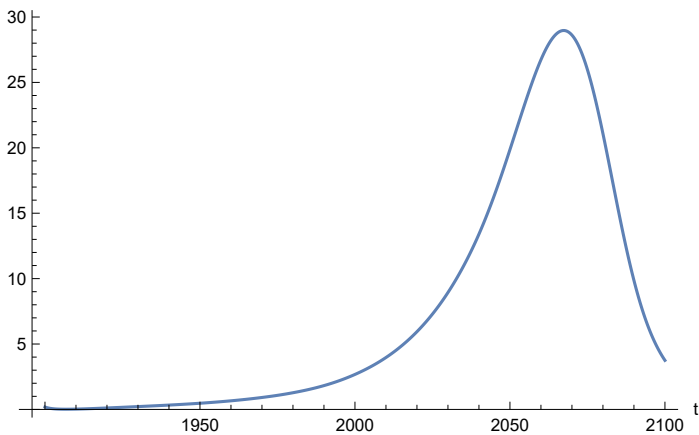


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 756.222
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



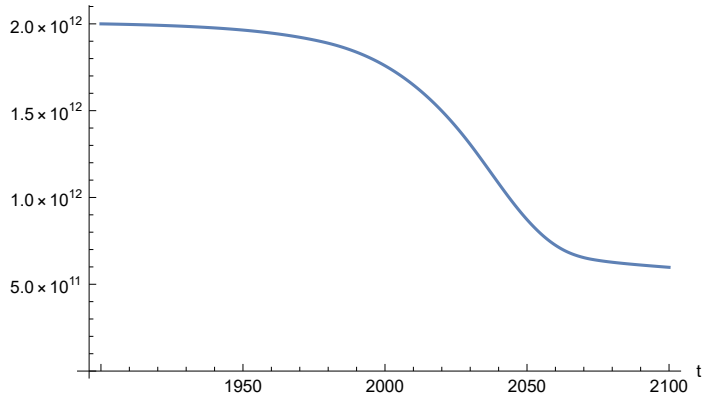
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 28.9686
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

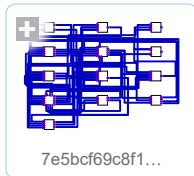


APPENDIX 75. LE/1.05, t_policy_year = 1970. Baseline Scenario 6, Experiment 75.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

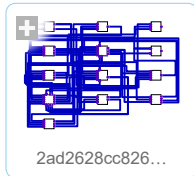
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

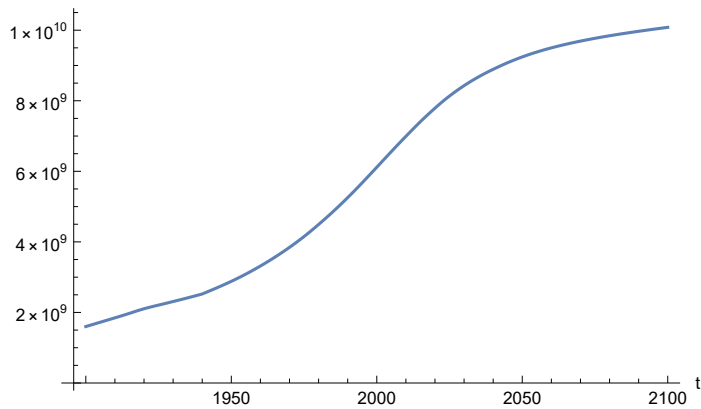
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W2ad2628cc8264cb8b1f394af14a5f615  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

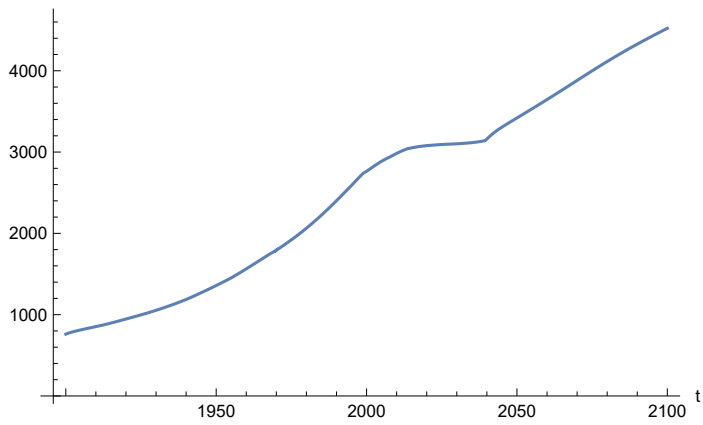
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $1.00813 \times 10^{10}$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

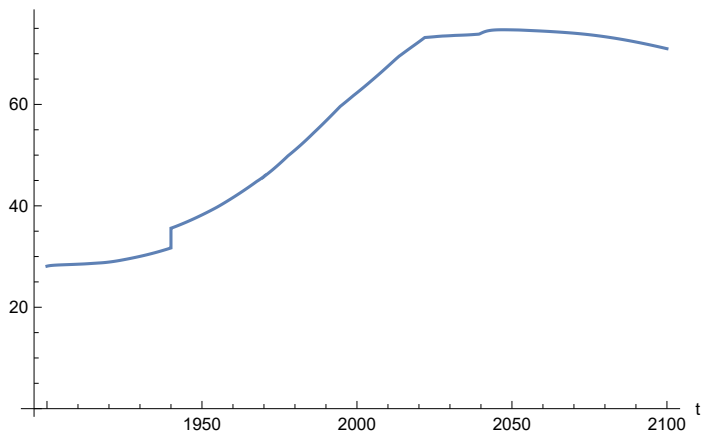
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

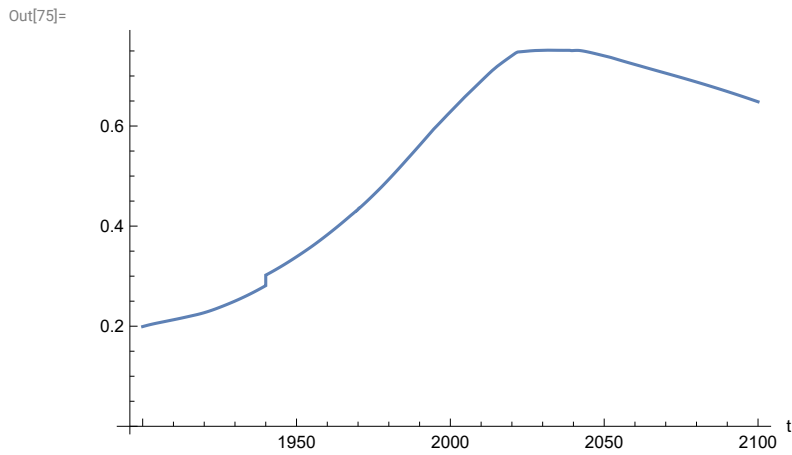
Out[73]=



In[74]:=

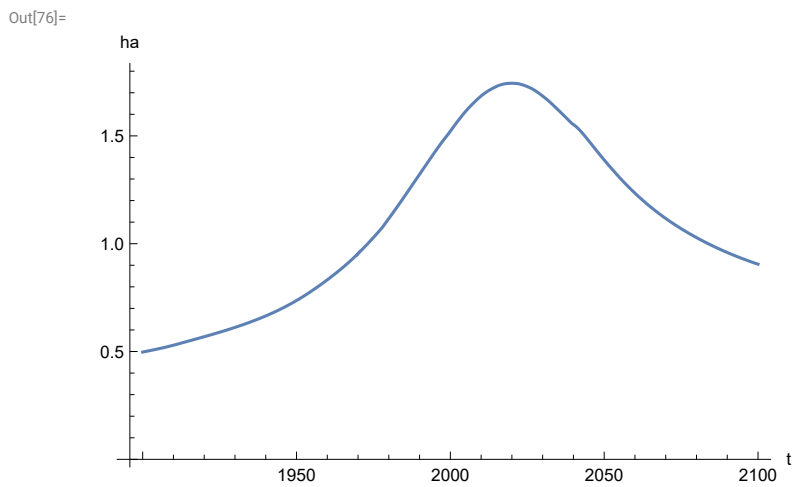
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



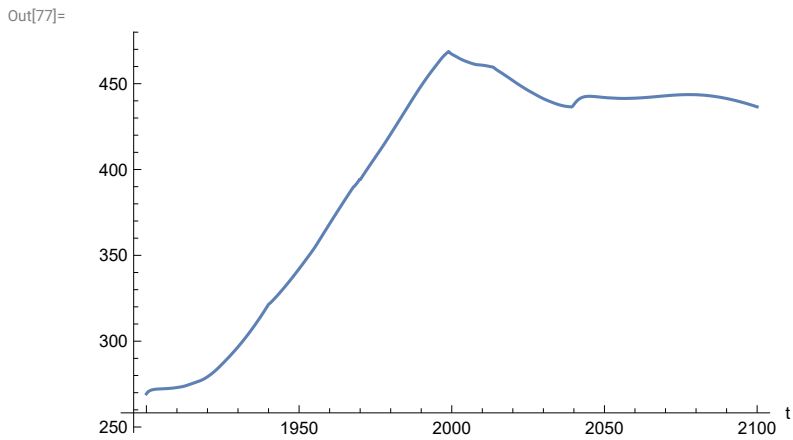
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



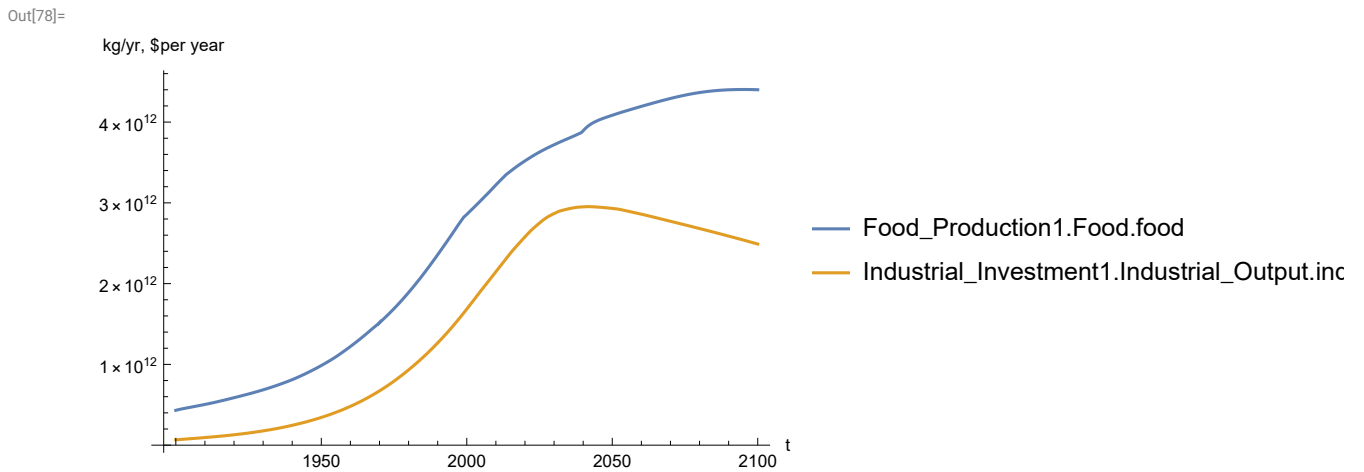
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

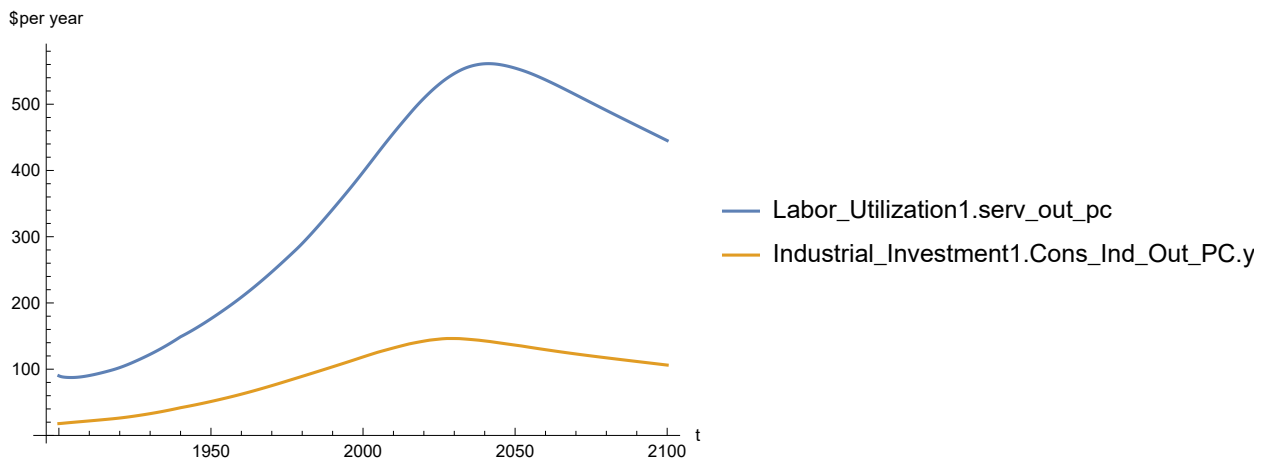
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

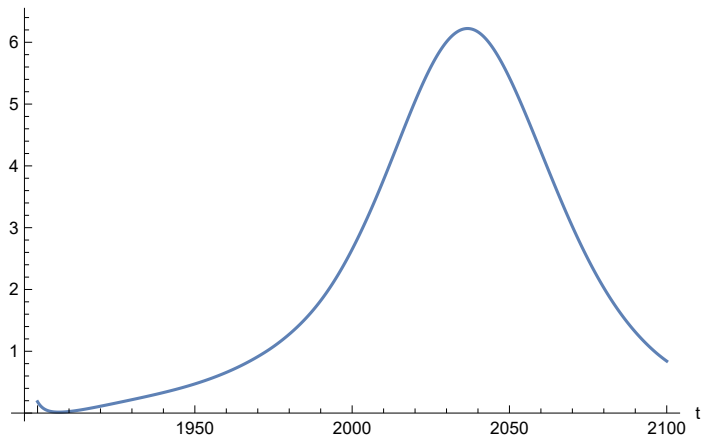
Maximum is 561.259

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

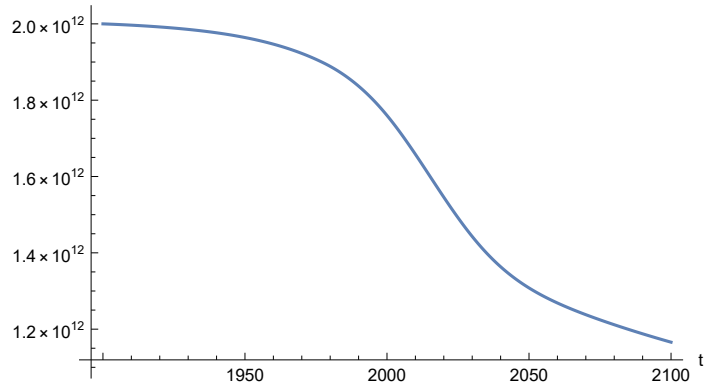
Maximum is 6.22275

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

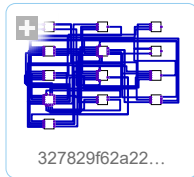
Out[83]=



APPENDIX 76. Baseline Scenario 6, Experiment 76. LE = LE/1.05, t_policity_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

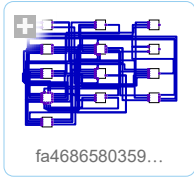
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```


Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



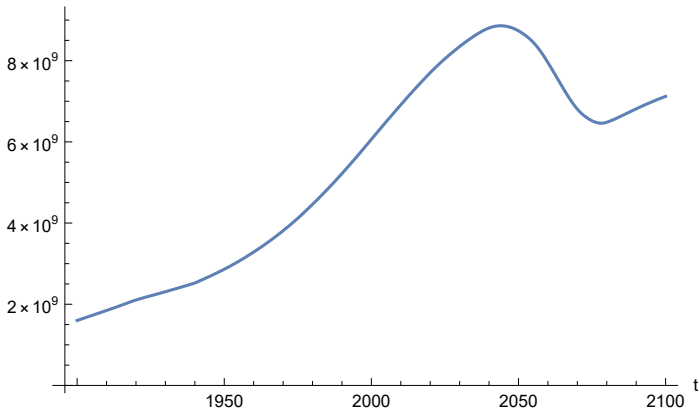
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

SystemModelSimulationData [ Model: Wfa46865803594f3c9ae3f967ecf4715c
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

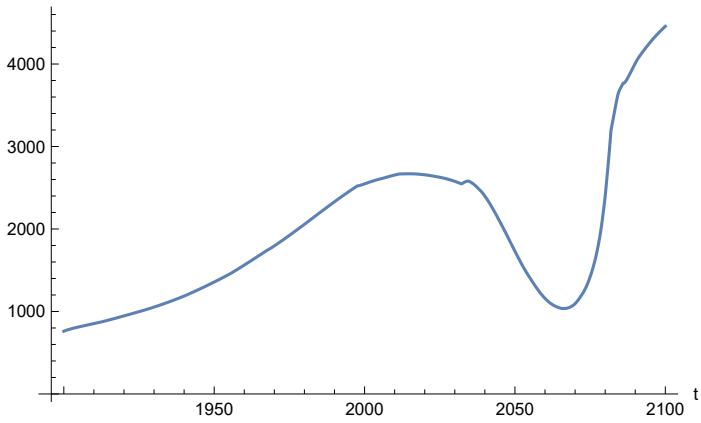


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.86024 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

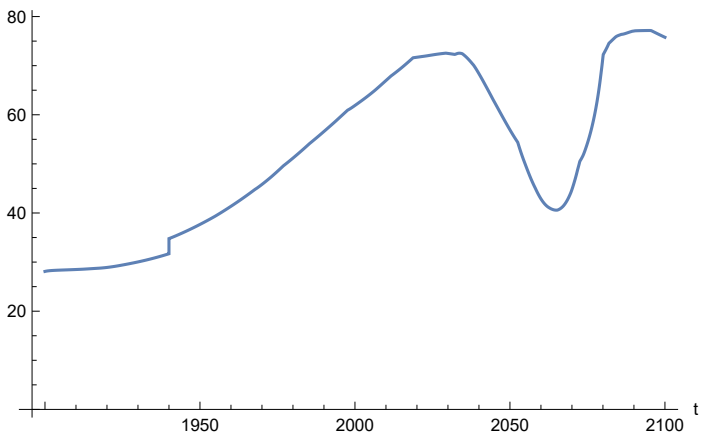
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

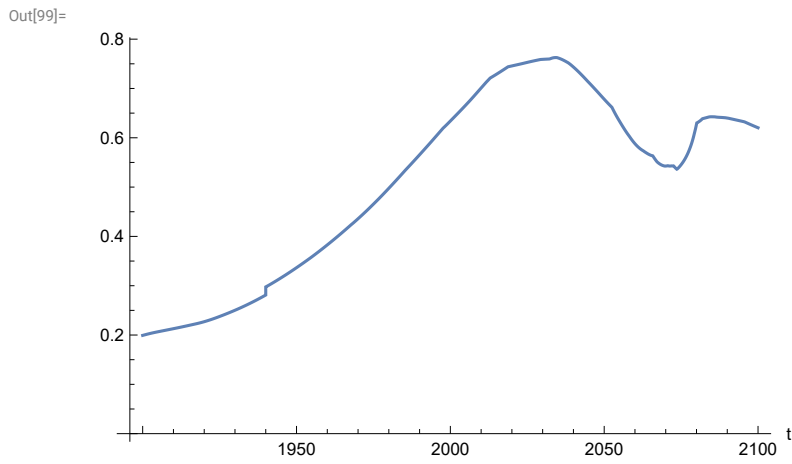
Out[97]=



In[98]:=

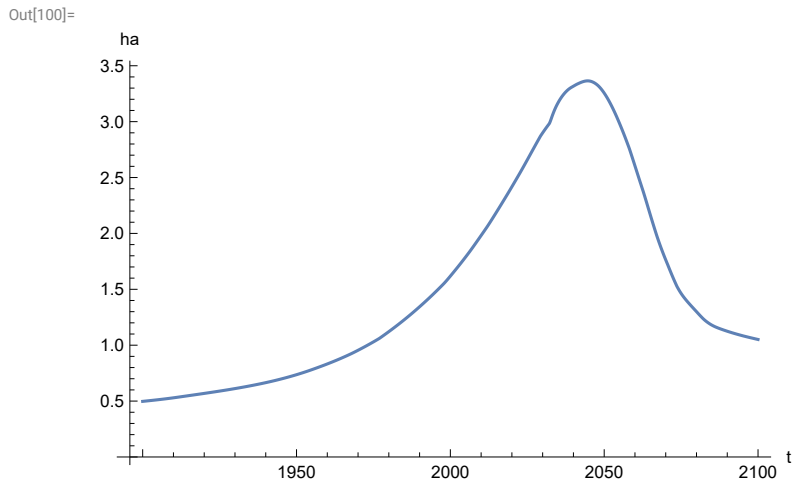
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

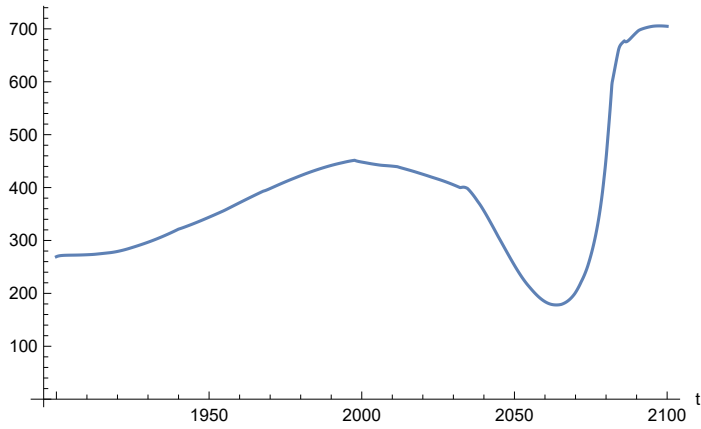


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

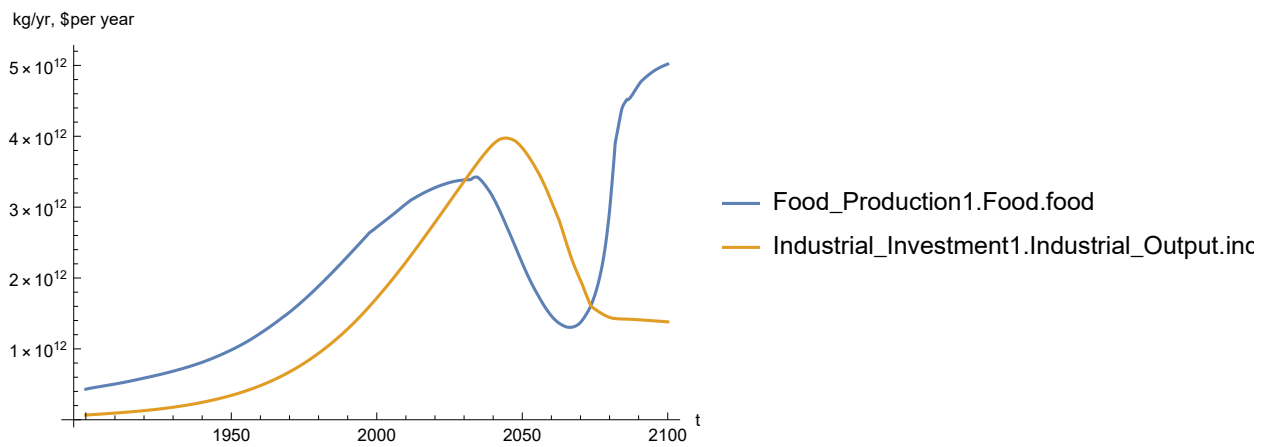


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

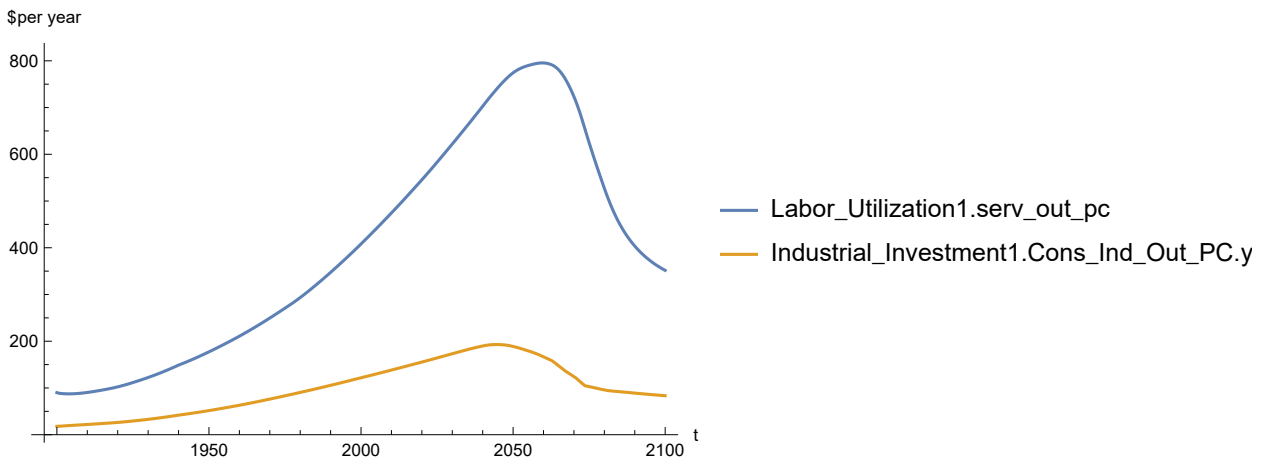


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim, {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

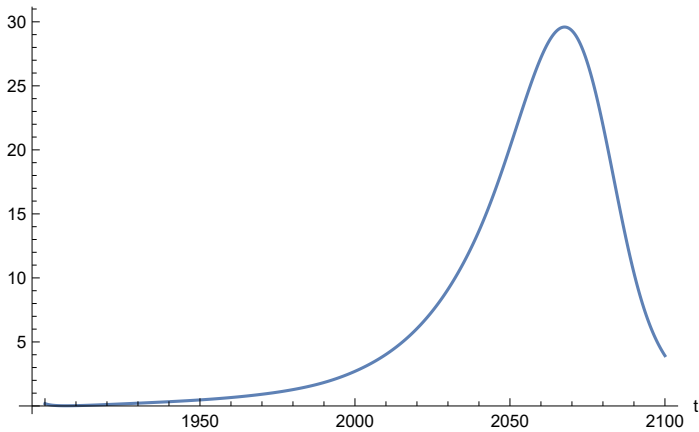
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 795.494
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 29.5921

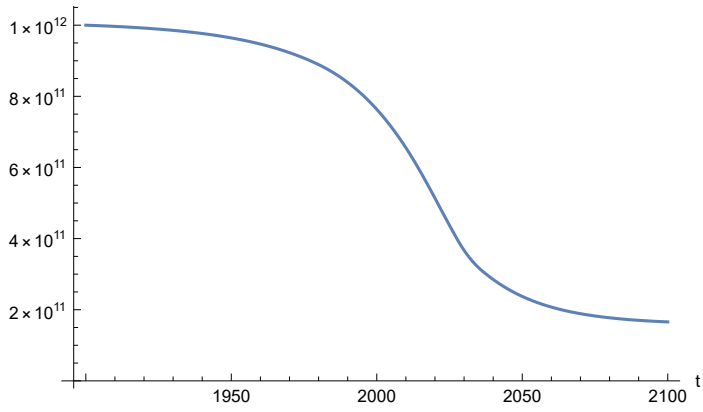
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[107]=



**APPENDIX 77. BENCHMARK SCENARIO 6, Experiment 77. LE = LE/1.1, t_policy_year = 1970.
Last modified: 30 July 2022/1100 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

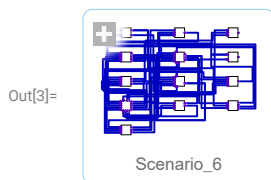
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

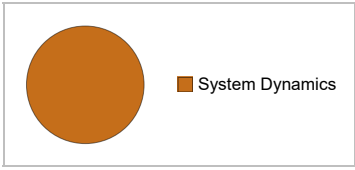
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 6.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_6"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_6
	Description	More accessible non-recoverable natural resources, pollution control, land yield enhancement, erosion pro
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background Color	True
Out[4]=	Simulation Start	265
	Simulation End	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

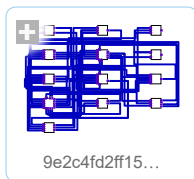
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

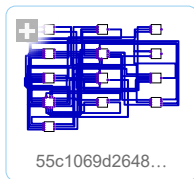
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

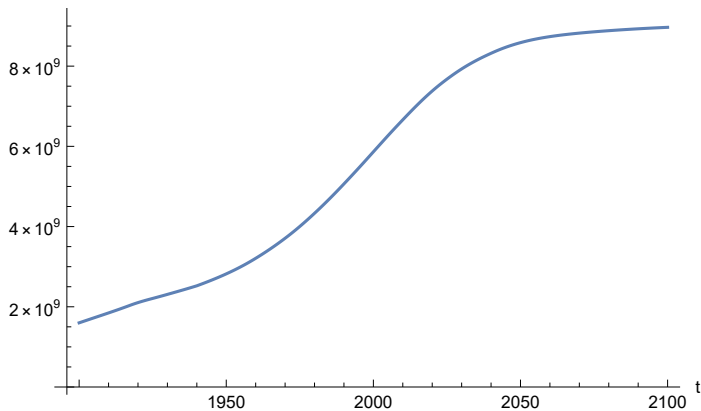
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W55c1069d264845e6a353aac0bfd60900
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

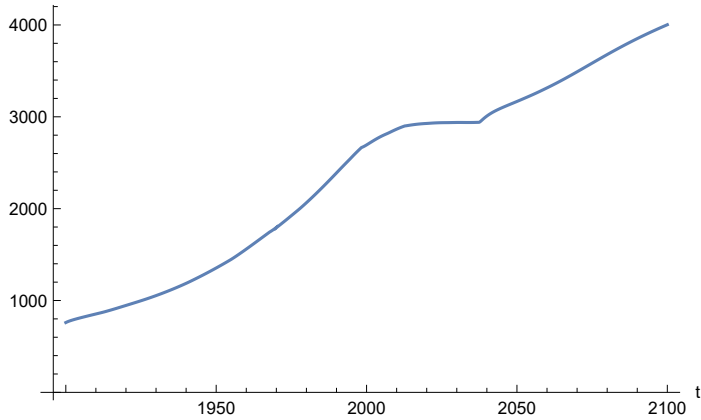
```
Out[22]=
```



Find max and min of population values.

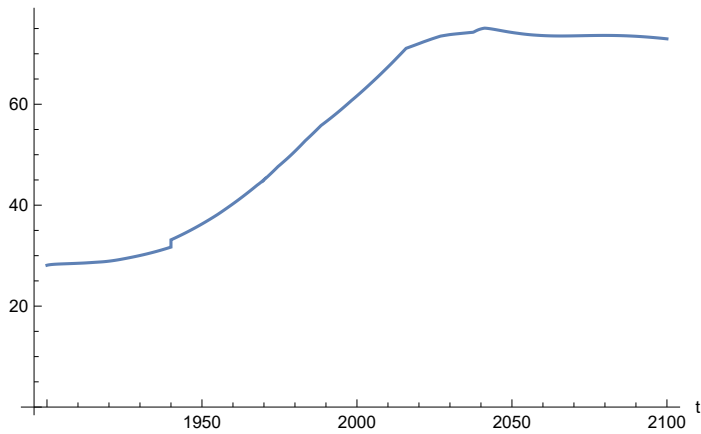
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.96736 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

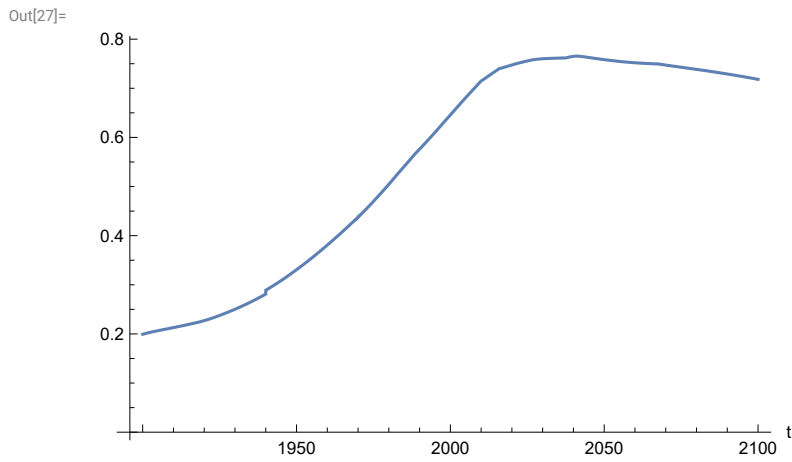
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```



```
In[26]:=
```

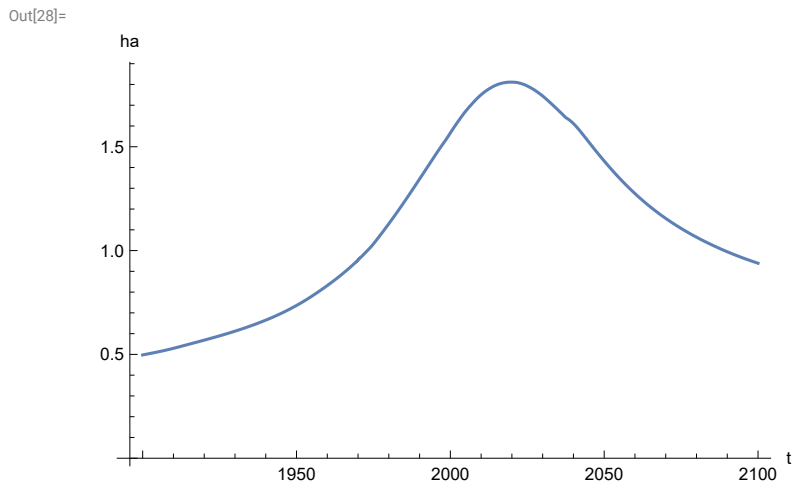
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

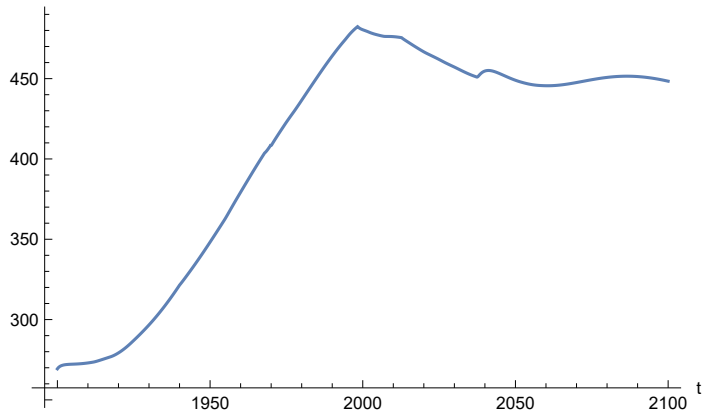
```
In[28]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

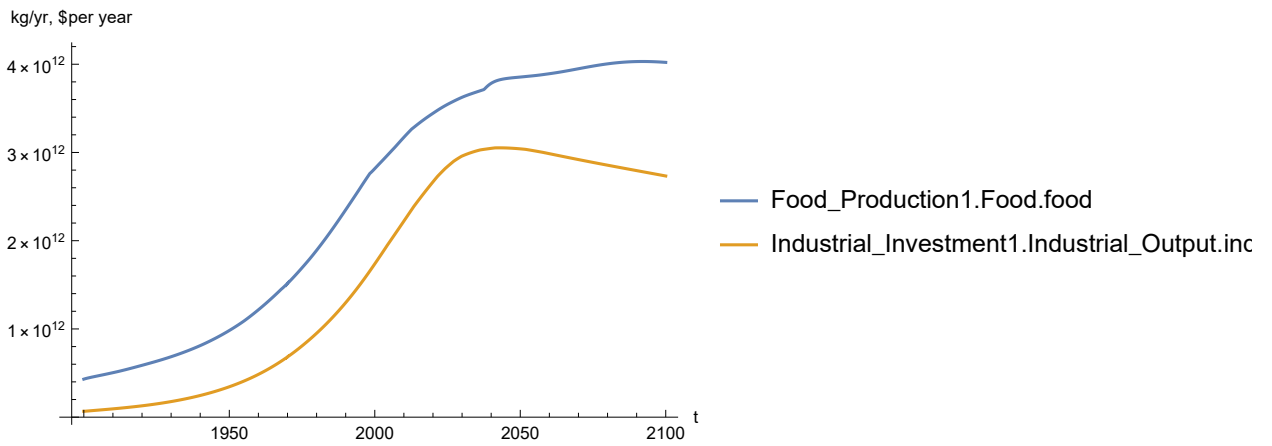
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

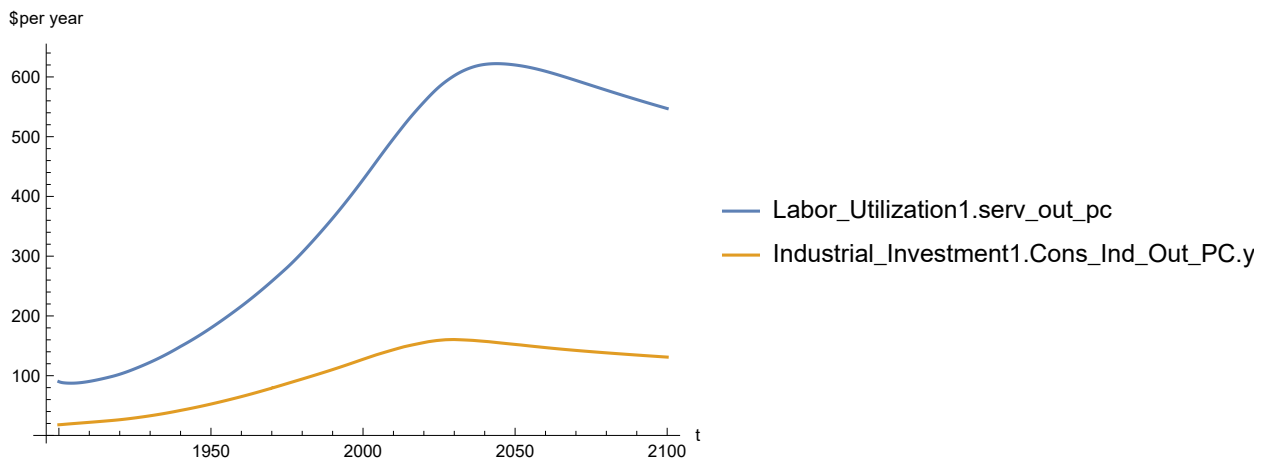
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



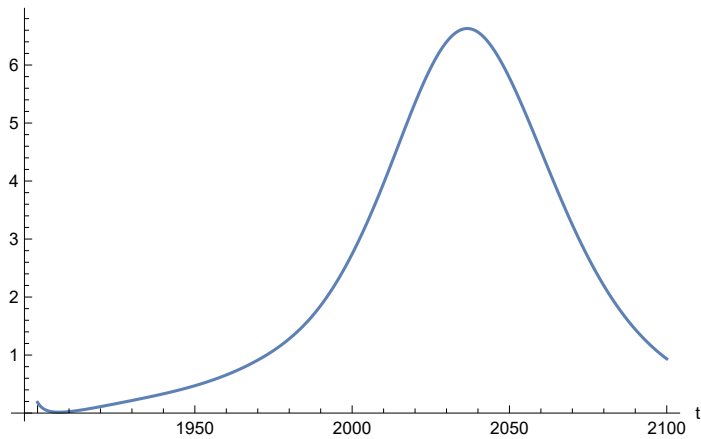
Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 622.214
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



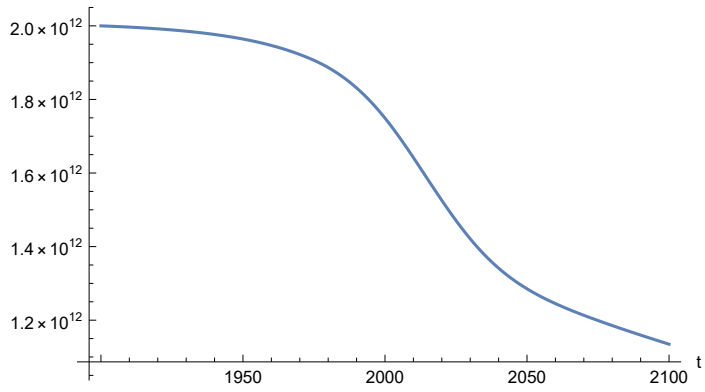
Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 6.62944
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

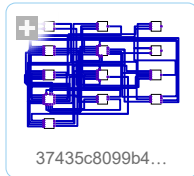


APPENDIX 78. LE/1.1, t_policy_year = 2025. Baseline Scenario 6, Experiment 78.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

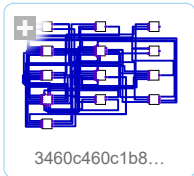
```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```


```
Out[44]=
```



Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

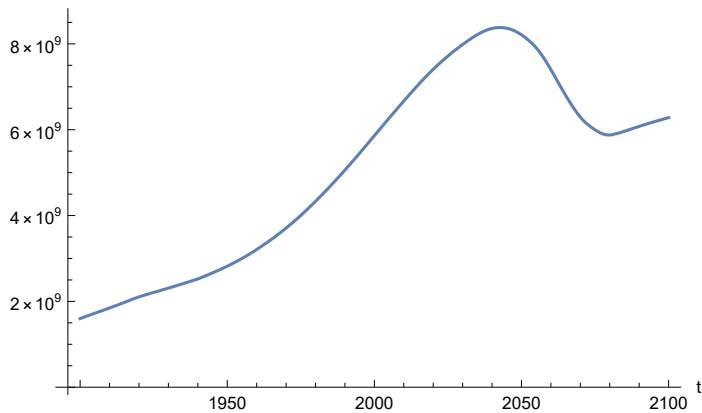
```
Out[45]=
```

```
SystemModelSimulationData [  Model: W3460c460c1b84e2e87faf0381aff9ce4
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[46]=
```



Find max and min of population values.

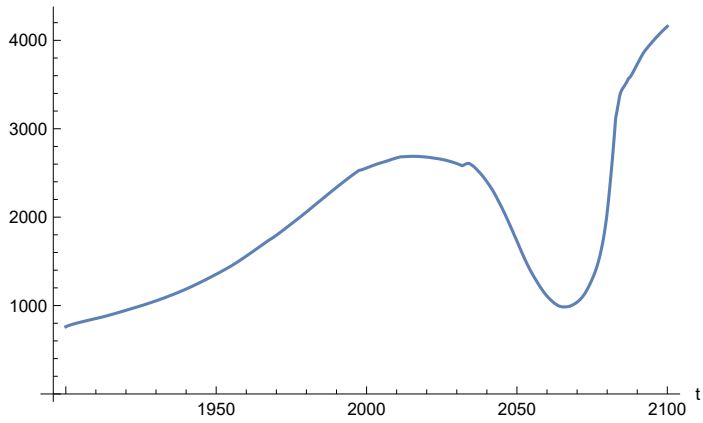
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.38016 × 109
```

```
Minimum is 1.6 × 109
```

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

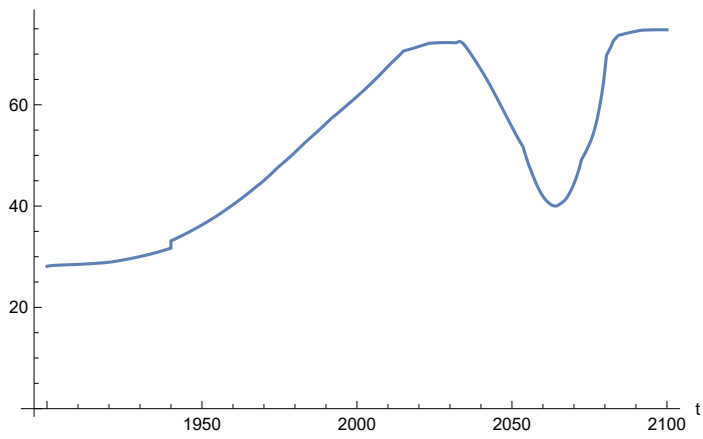
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[49]=



In[50]:=

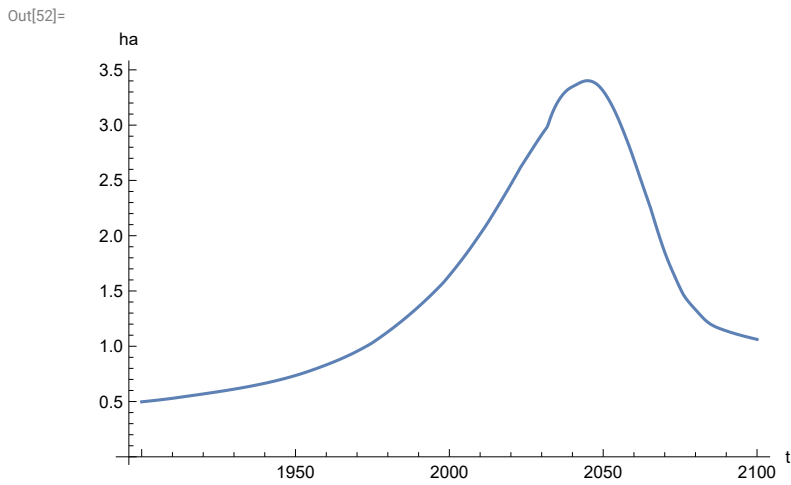
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

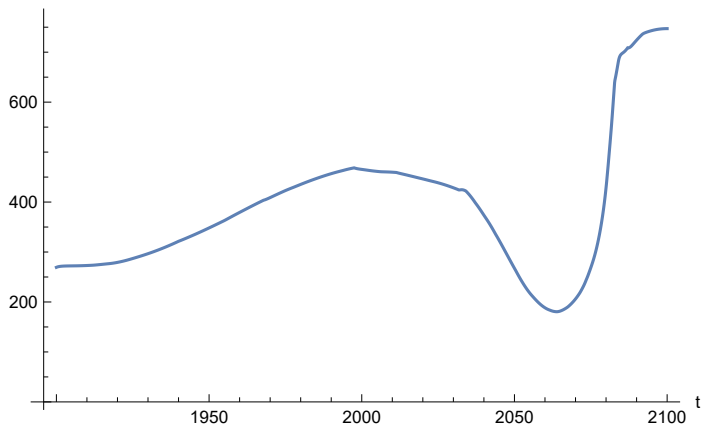
```
In[52]:= SystemModelPlot[basesim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

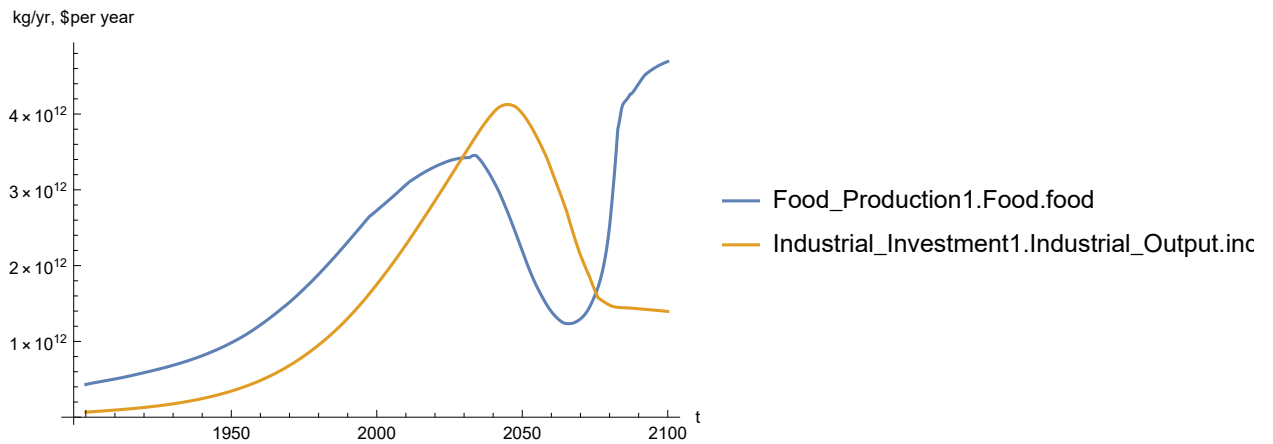
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

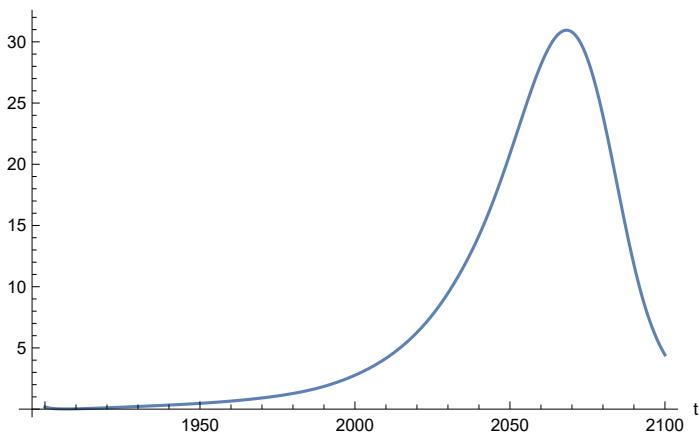


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 902.738
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



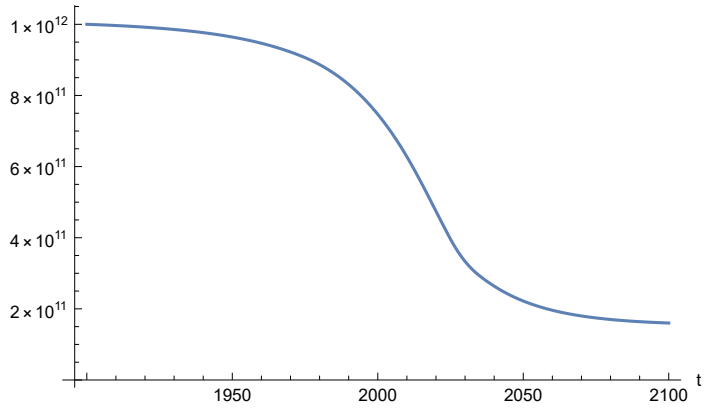
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 30.9503
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=



APPENDIX 6A1. BENCHMARK SCENARIO 8, Experiment 6A1. $LE = LE/1.001$, $t_{policy_year} = 2002$.

Last modified: 31 July 2022/1405 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

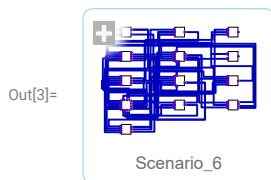
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

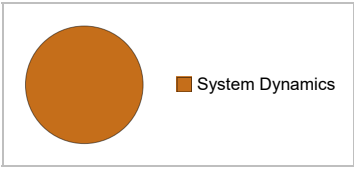
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 6.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_6"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_6
	D	More accessible non-recoverable natural resources, pollution control, land yield enhancement, erosion pro
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

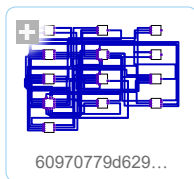
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```

In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}

In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
Out[18]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}

In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
Out[19]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}

```

Execute and plot various variables.

```

In[20]:= basesim = SystemModelSimulate[strsim]
Out[20]=
SystemModelSimulationData [  Model: W60970779d629433ebce848170b07ada2  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]

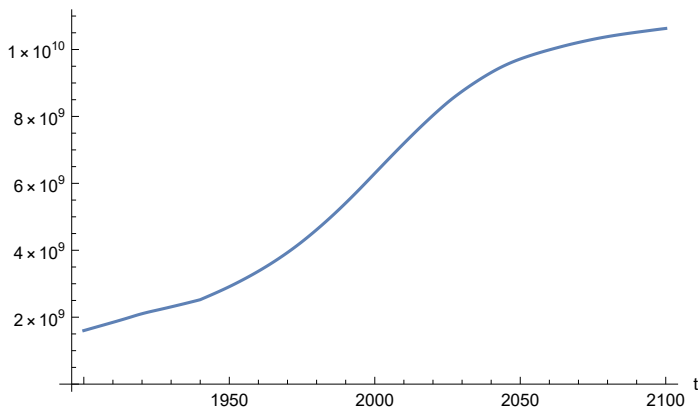
```

Plot total population, people.

```

In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[21]=

```



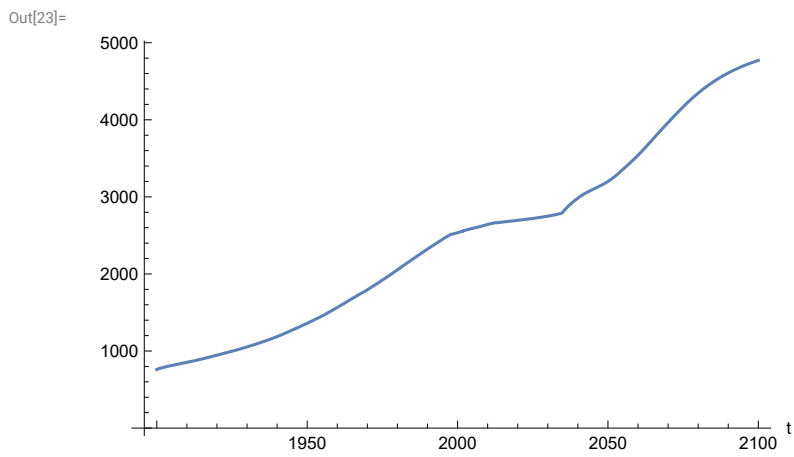
Find max and min of population values.

```

In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $1.06293 \times 10^{10}$ 
Minimum is  $1.6 \times 10^9$ 

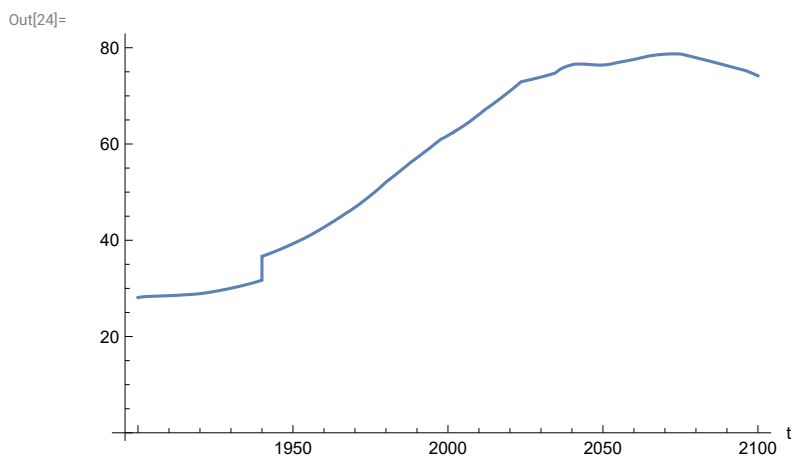
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]



Plot life expectancy, years.

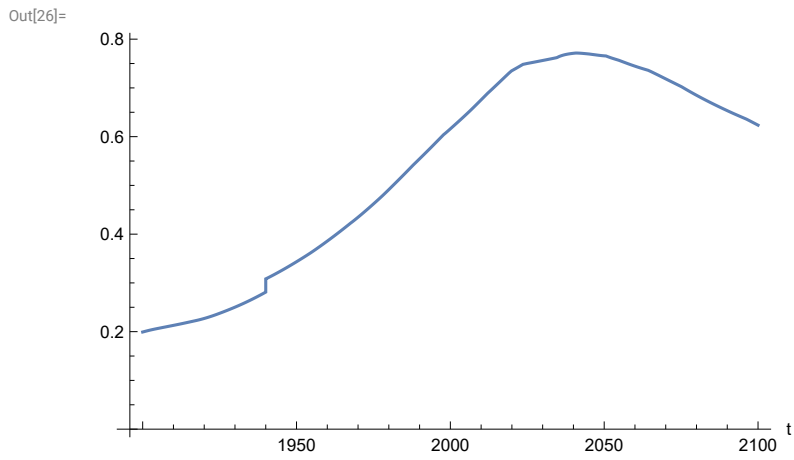
In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]



In[25]:=

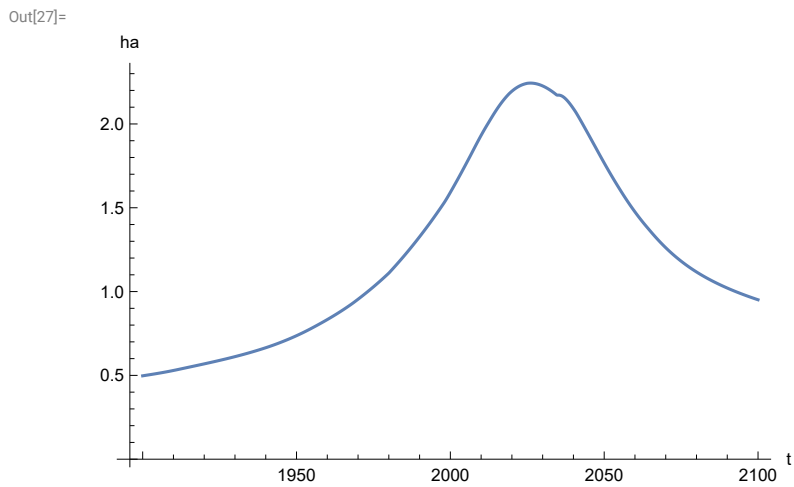
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

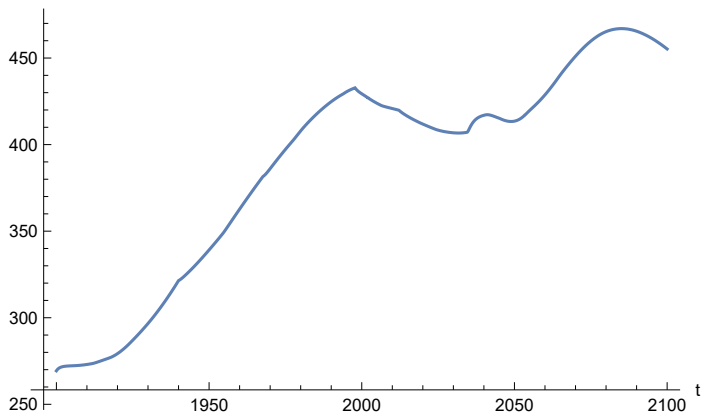
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

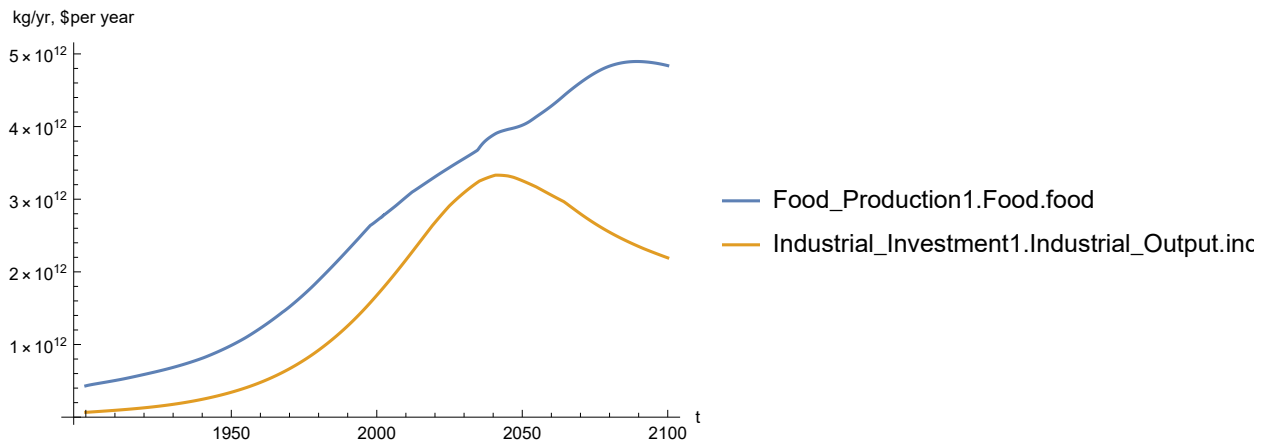
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

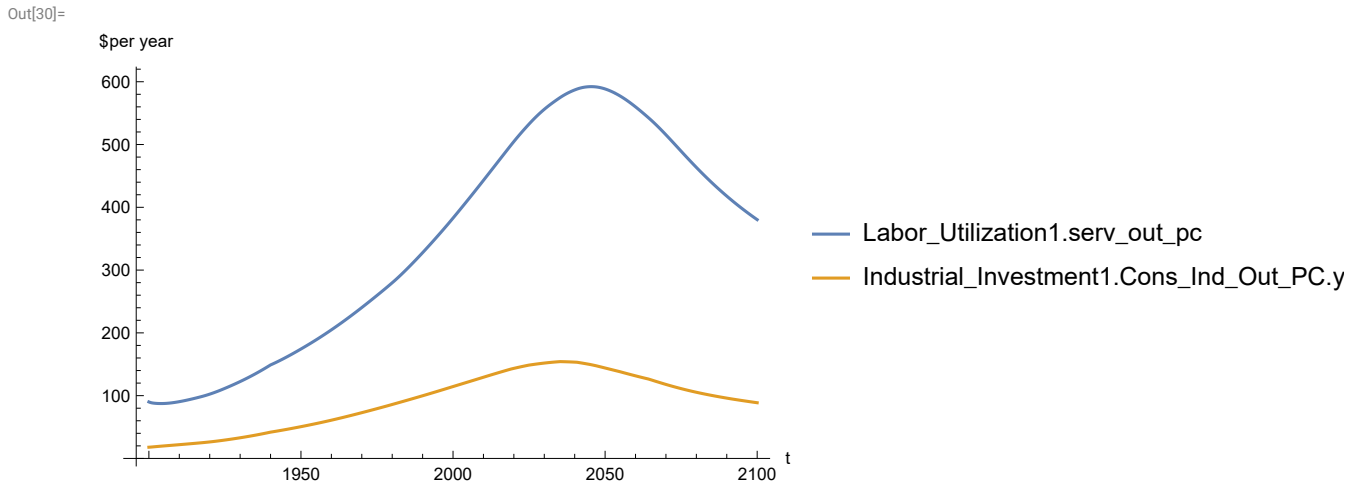
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

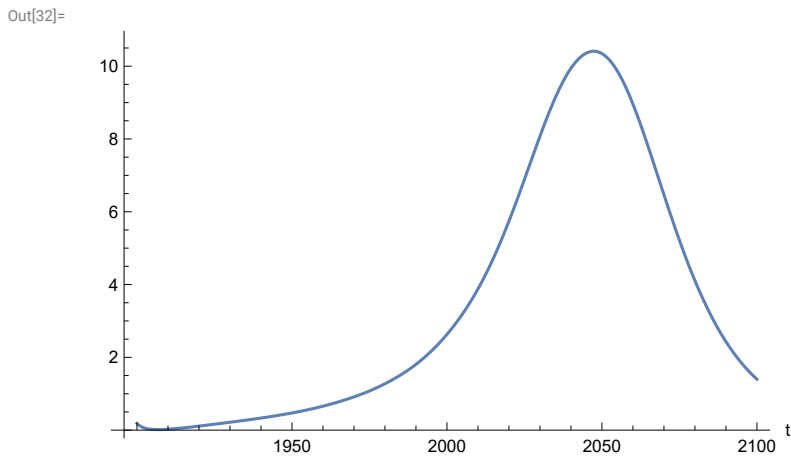


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 592.186
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



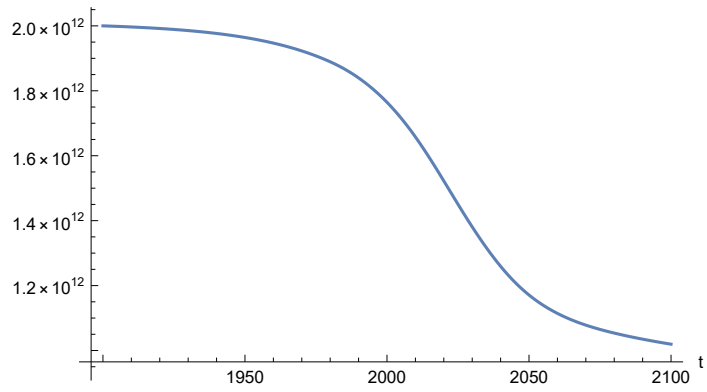
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.4113
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

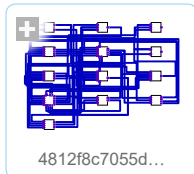


APPENDIX 6A2. LE/1.01, t_policy_year =2002. Baseline Scenario 8, Experiment 6A2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98}} |>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=


```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

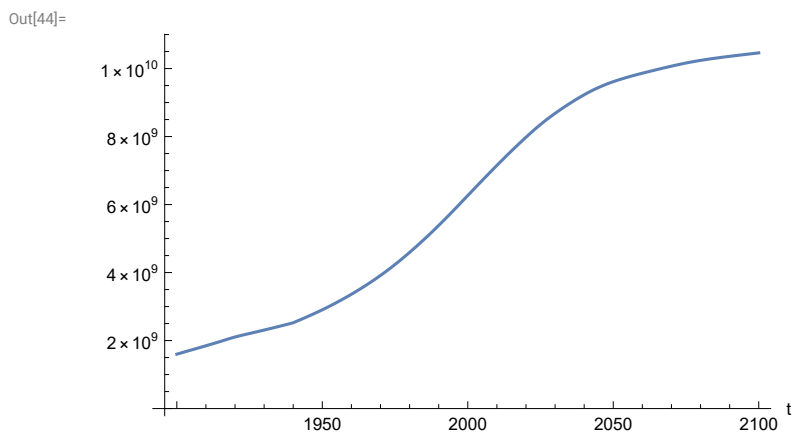
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: W4812f8c7055d4d8cbf8e7e24393698d7
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

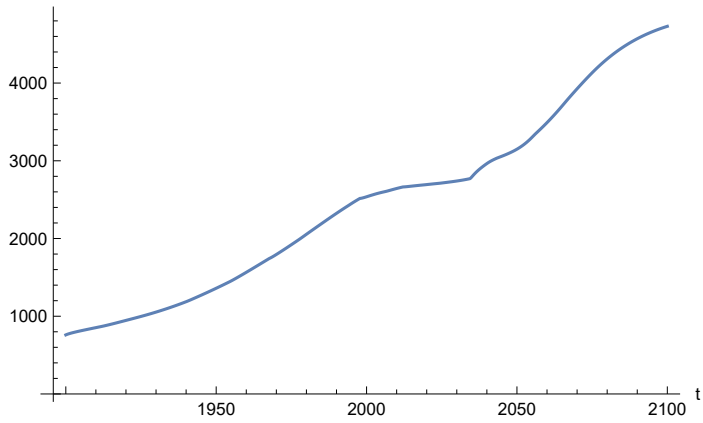
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $1.04605 \times 10^{10}$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

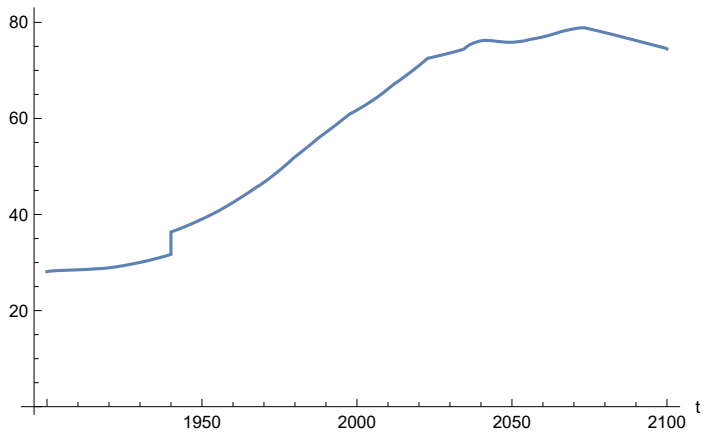
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

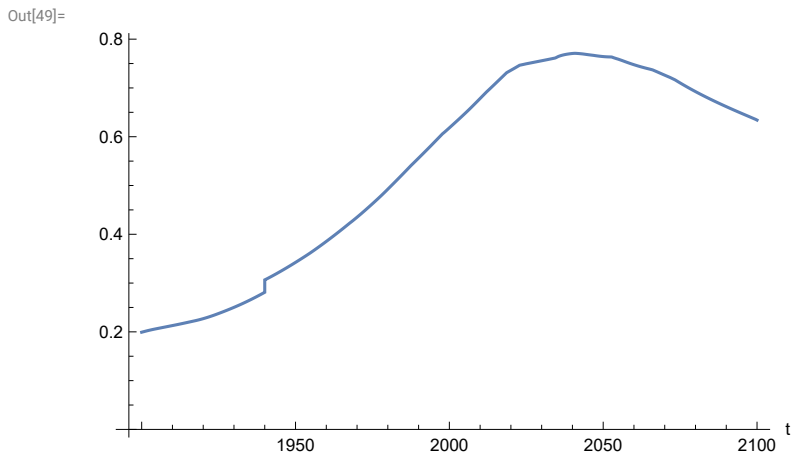
Out[47]=



In[48]:=

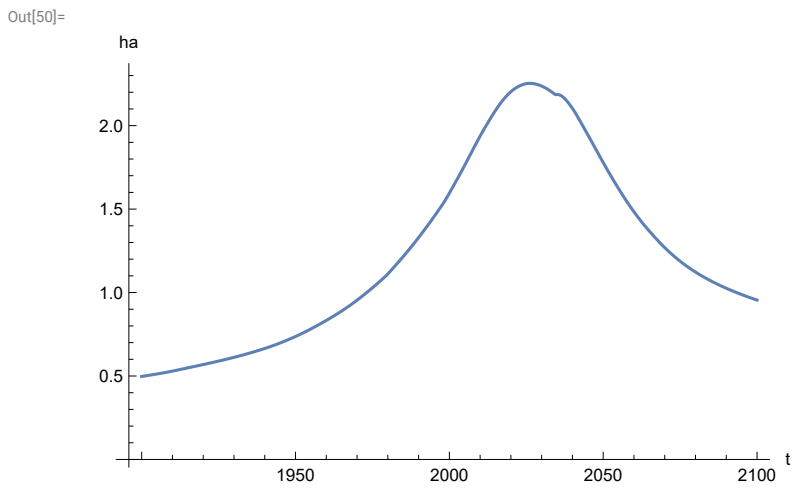
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



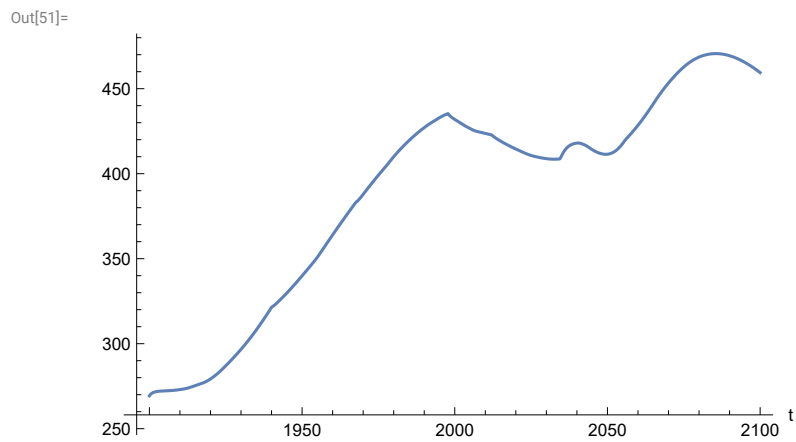
Plot per capita ecological footprint, hectares.

```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



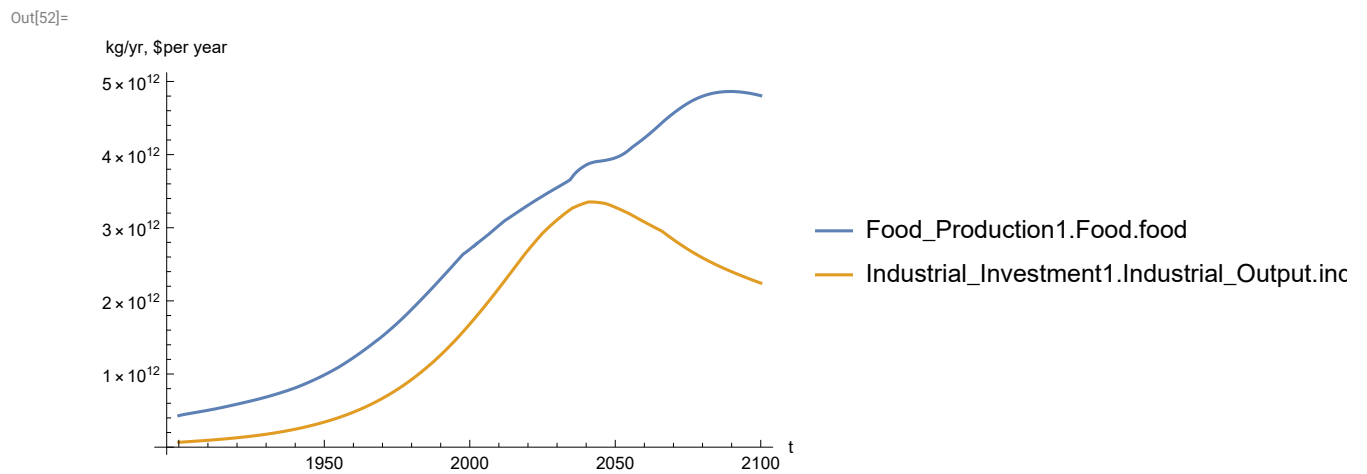
Plot food production per capita (kg/year).

```
In[51]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



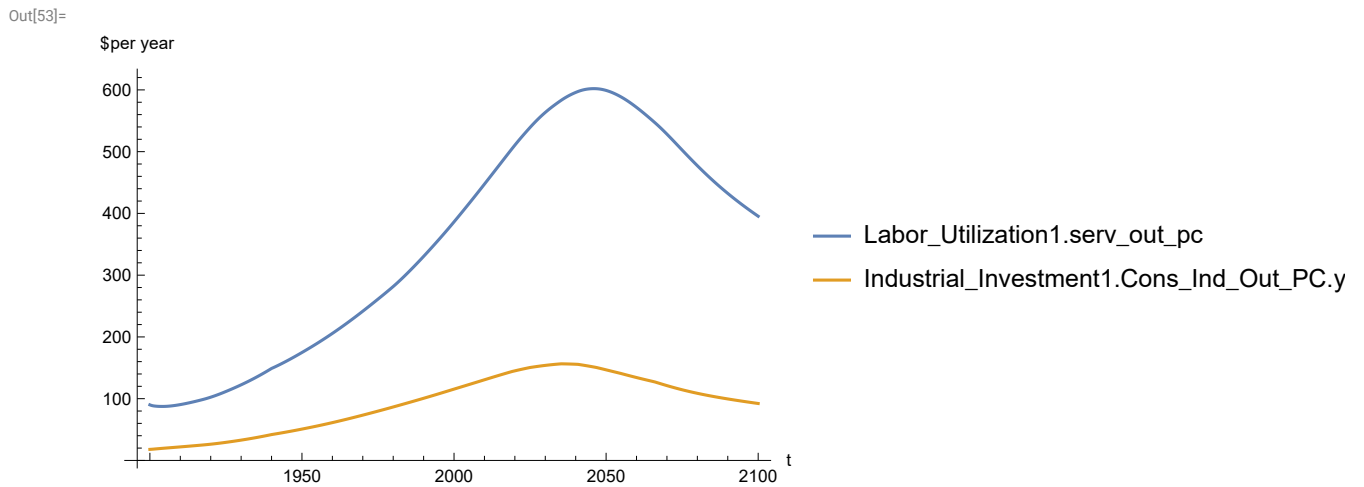
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[52]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

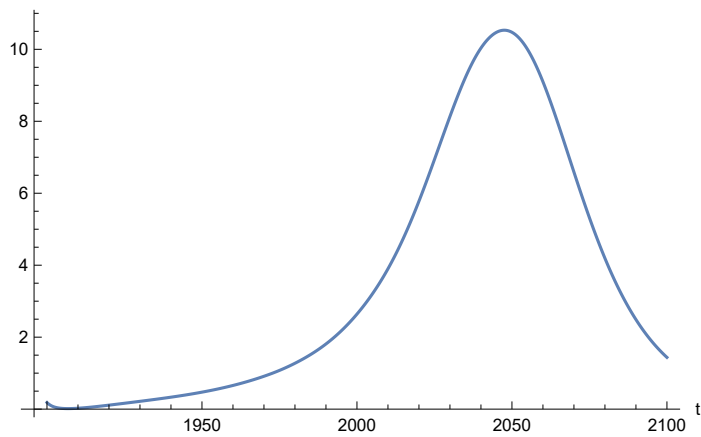


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 602.024
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



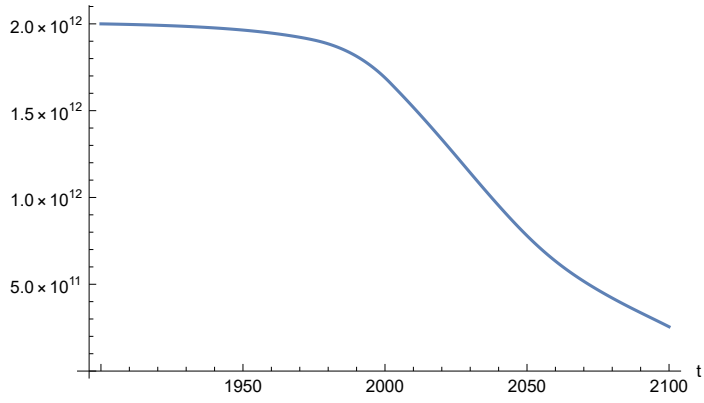
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.5309
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 6B1. BENCHMARK SCENARIO 8, Experiment 6B1. $LE = LE/1.03$, $t_policy_year = 2002$.

Last modified: 27 July 2022/1430 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

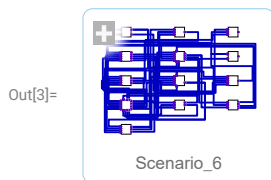
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

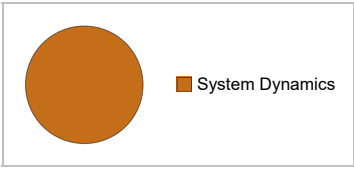
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 6.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_6"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_6
	D	More accessible non-recoverable natural resources, pollution control, land yield enhancement, erosion pro
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

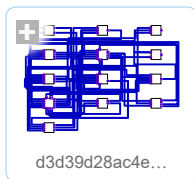
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```


```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

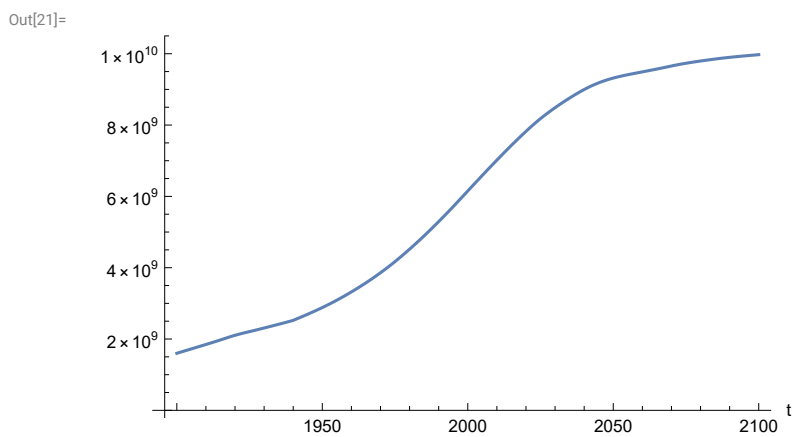
Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

```
Out[20]= SystemModelSimulationData [  Model: Wd3d39d28ac4e40cabd354f713c59843b
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

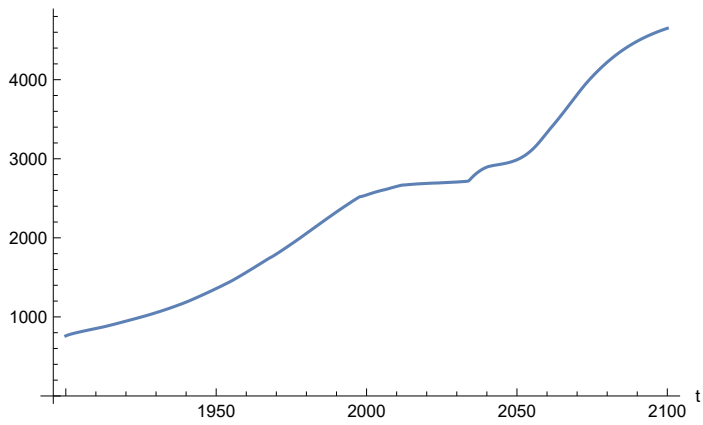
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.9737 × 109
```

```
Minimum is 1.6 × 109
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

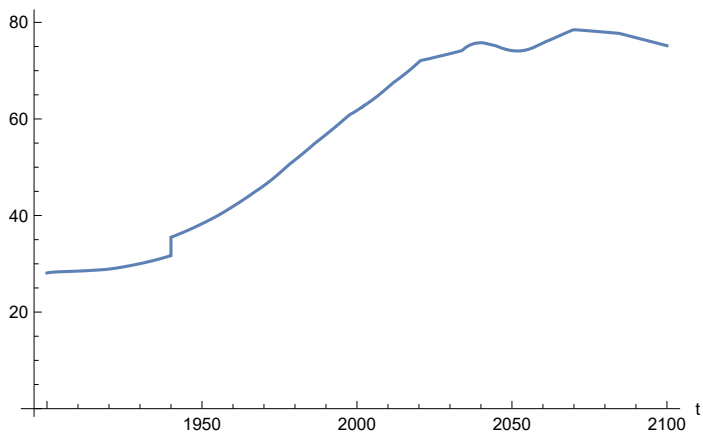
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

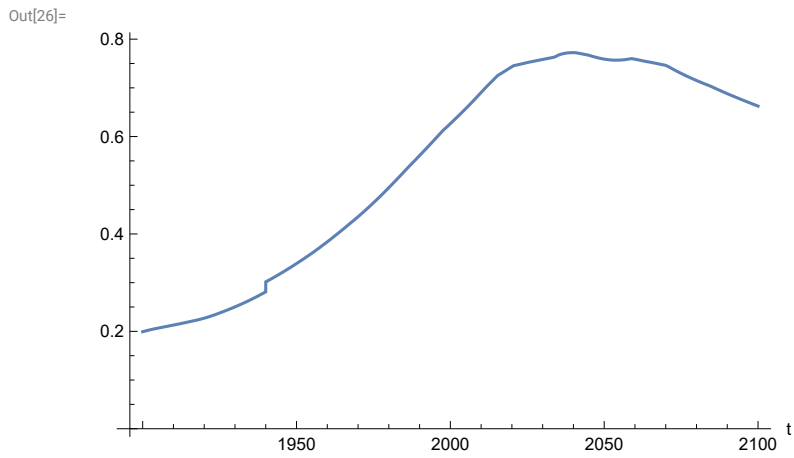
Out[24]=



In[25]:=

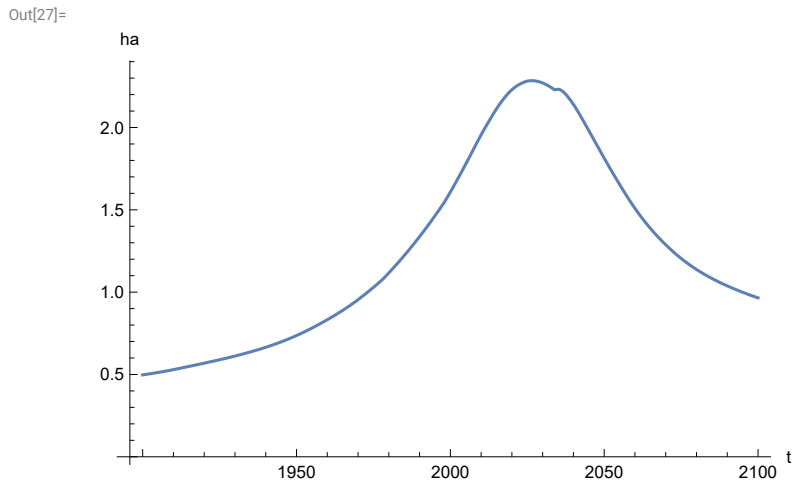
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

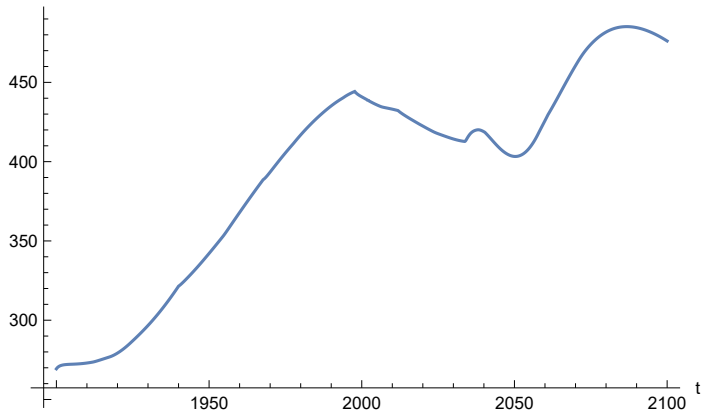
```
In[27]:= SystemModelPlot[basesim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]**

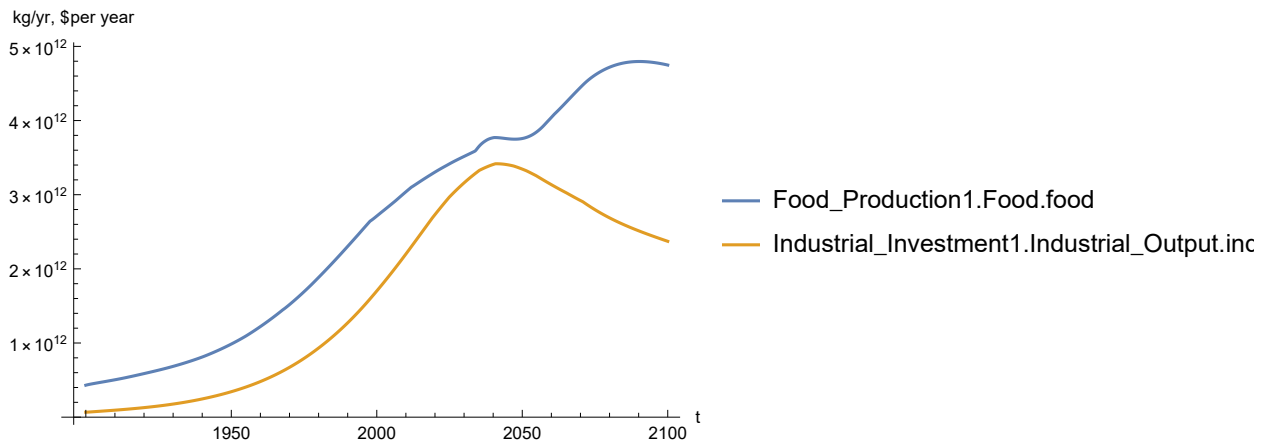
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

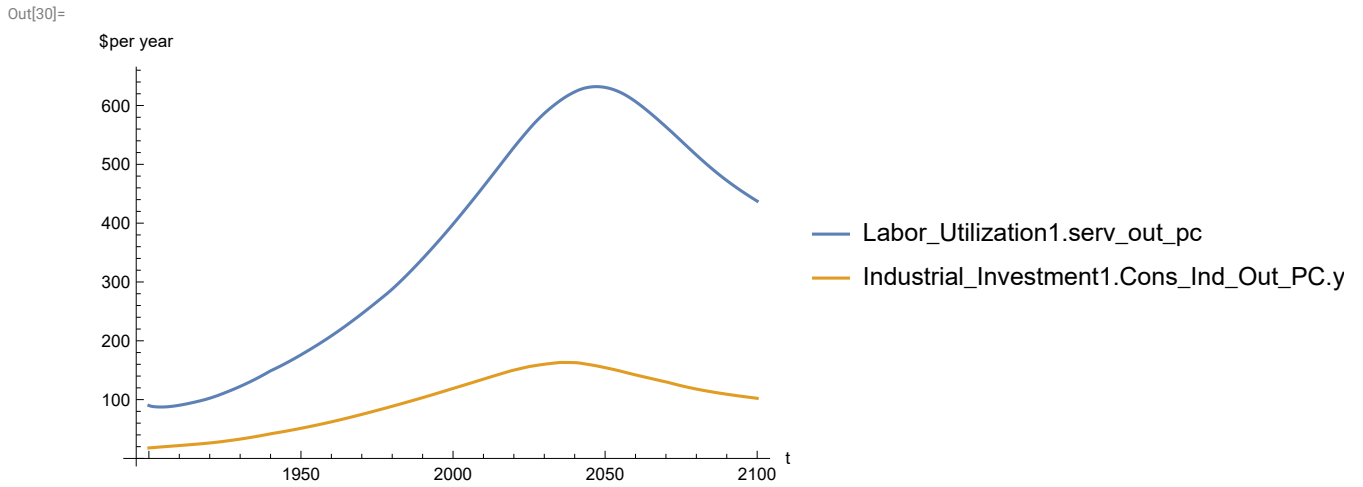
In[29]:= **SystemModelPlot[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

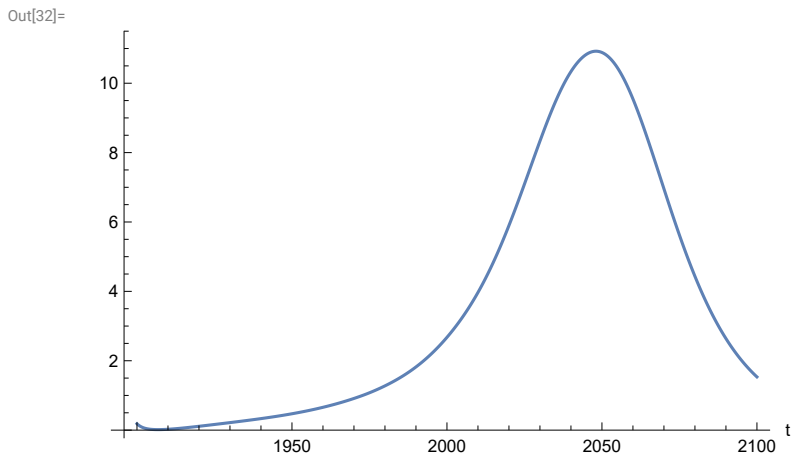


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 632.087
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



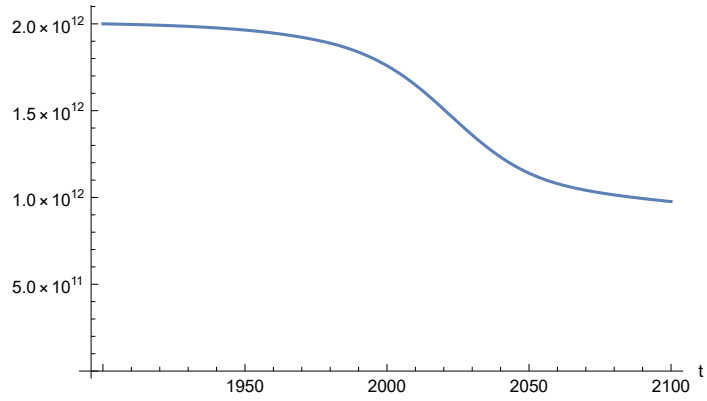
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.9227
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

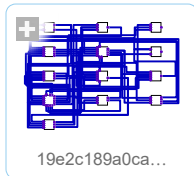


APPENDIX 6B2. LE/1.05, t_policy_year = 2002. Baseline Scenario 8, Experiment 6B2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=


```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

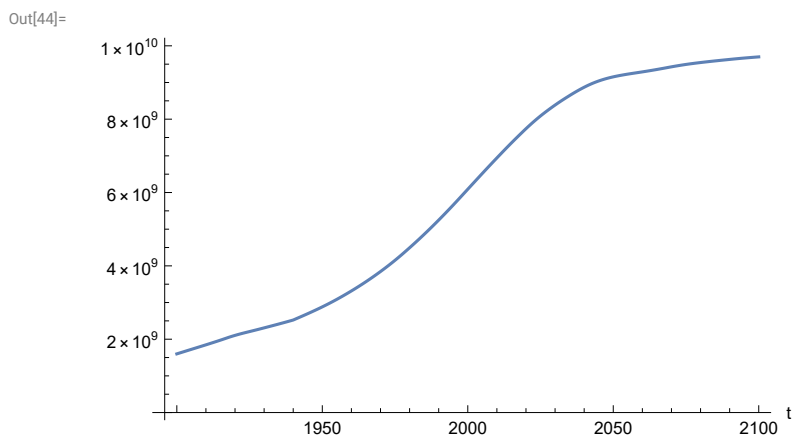
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: W19e2c189a0ca4412854388f38eeaa195
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

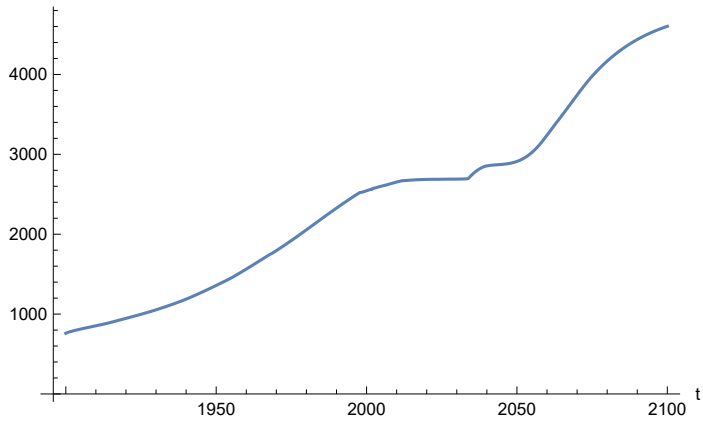
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $9.69841 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

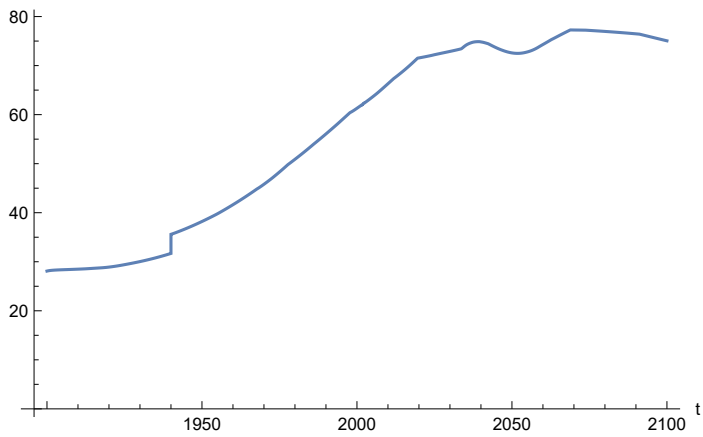
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

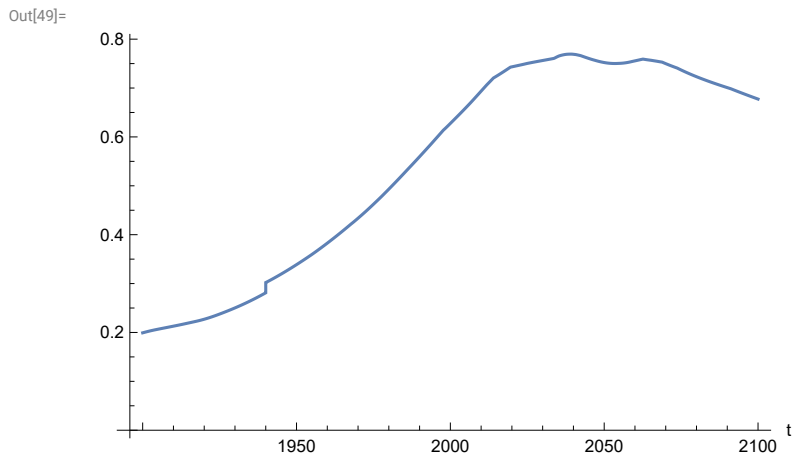
Out[47]=



In[48]:=

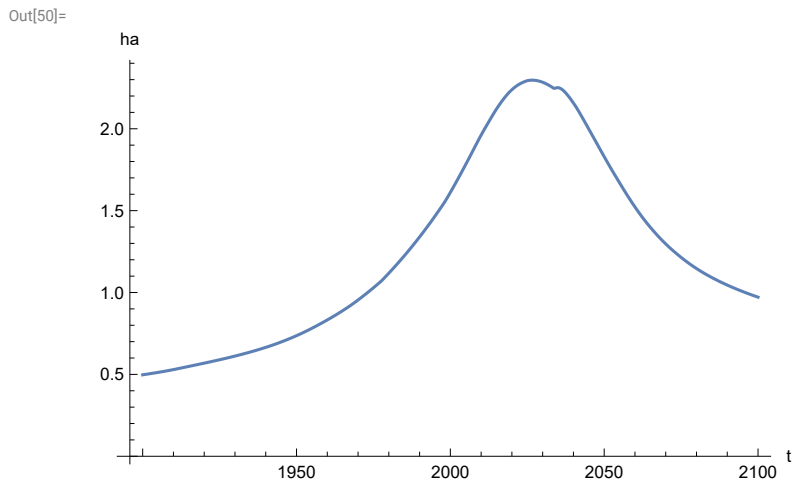
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

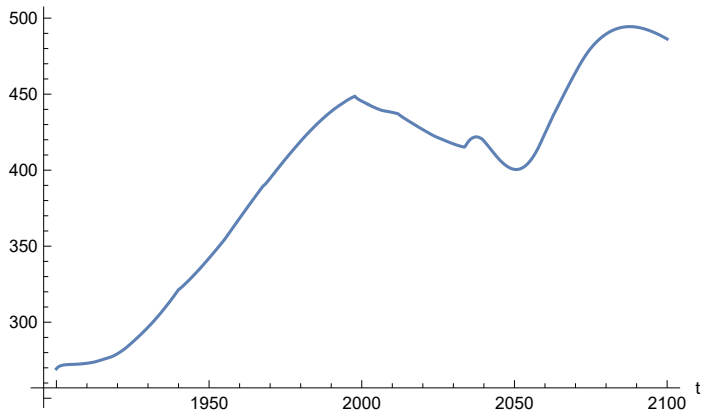
```
In[50]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]**

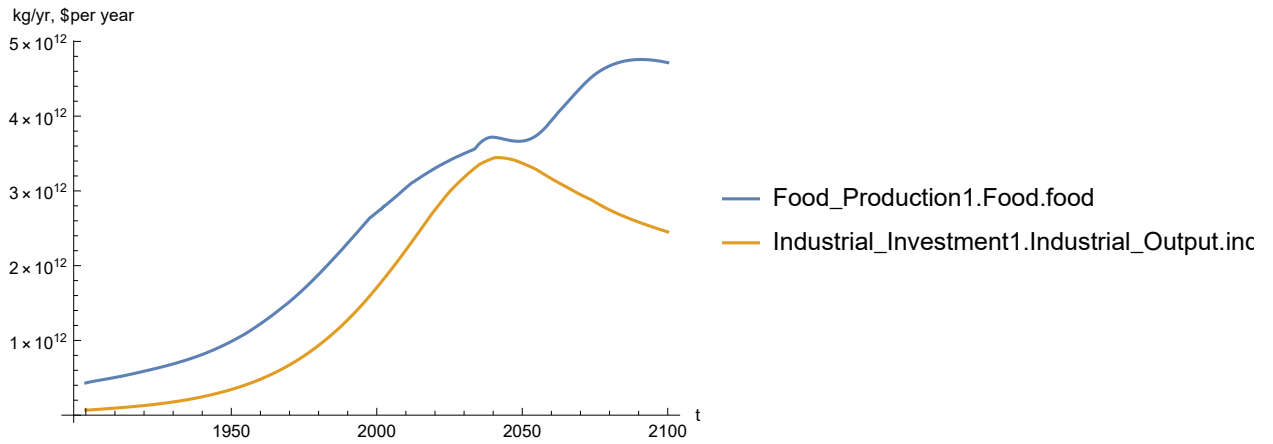
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[52]:= **SystemModelPlot[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

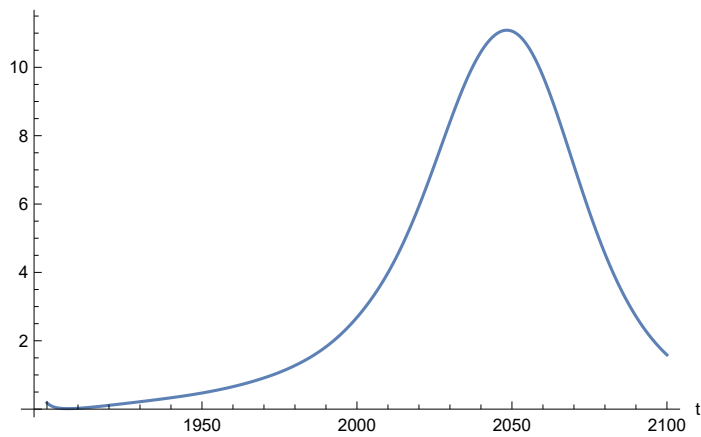


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 648.369
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



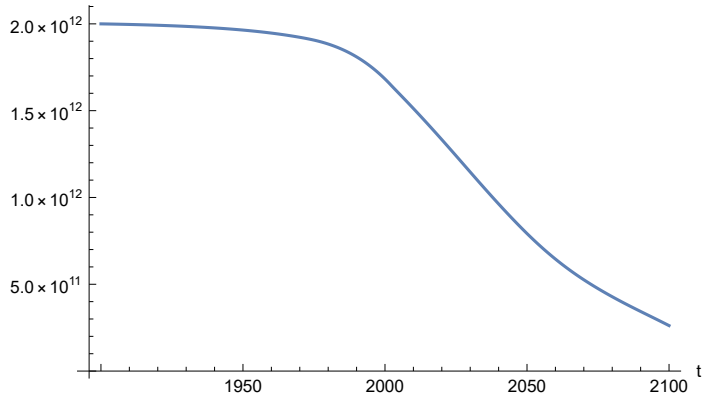
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.0858
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 6C1. BENCHMARK SCENARIO 8, Experiment 6C1. $LE = LE/1.1$, $t_policy_year = 2002$.

Last modified: 30 July 2022/1530 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

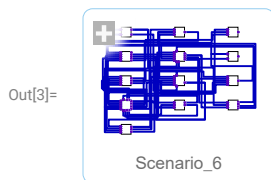
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

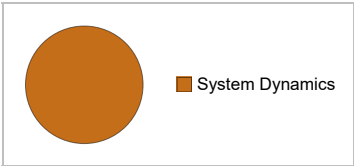
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 6.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_6"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_6
	D	More accessible non-recoverable natural resources, pollution control, land yield enhancement, erosion pro
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

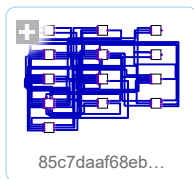
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

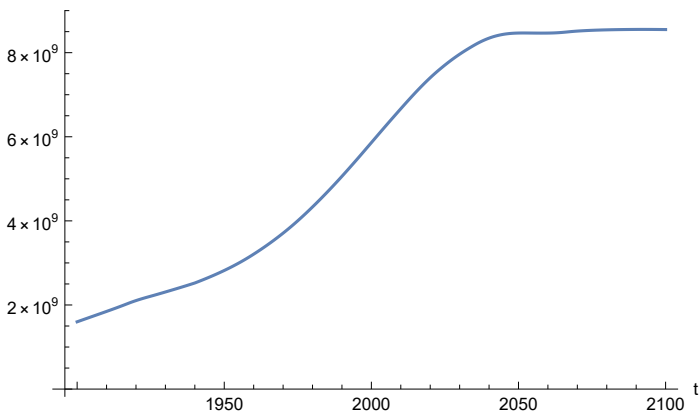
```
Out[20]=
```

```
SystemModelSimulationData [  Model: W85c7daaf68eb48aca8bfc65902b7d164  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

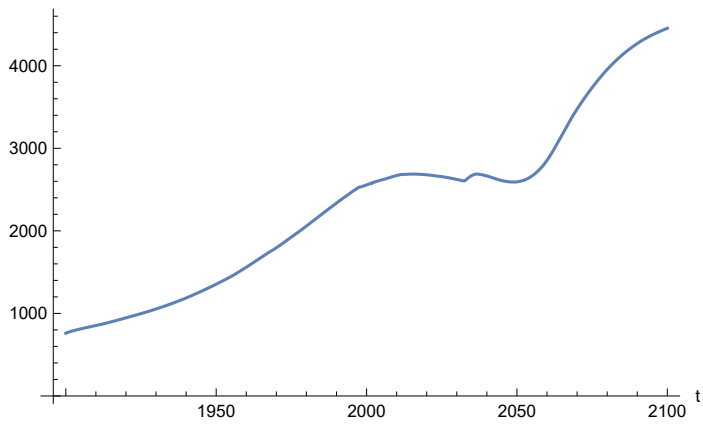
```
In[22]:= MinAndMax[basesim [{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.55303 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

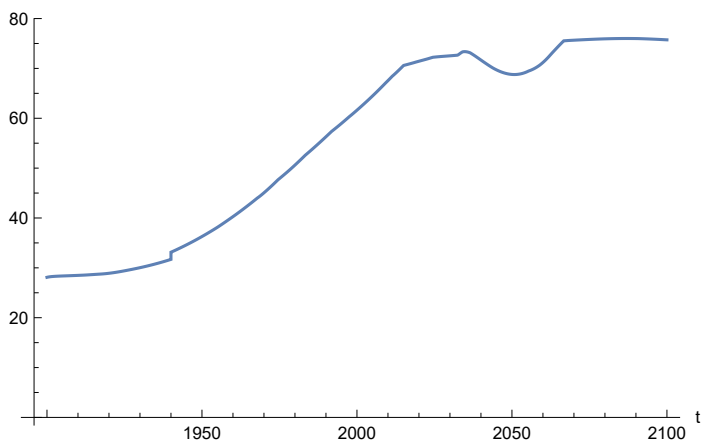
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

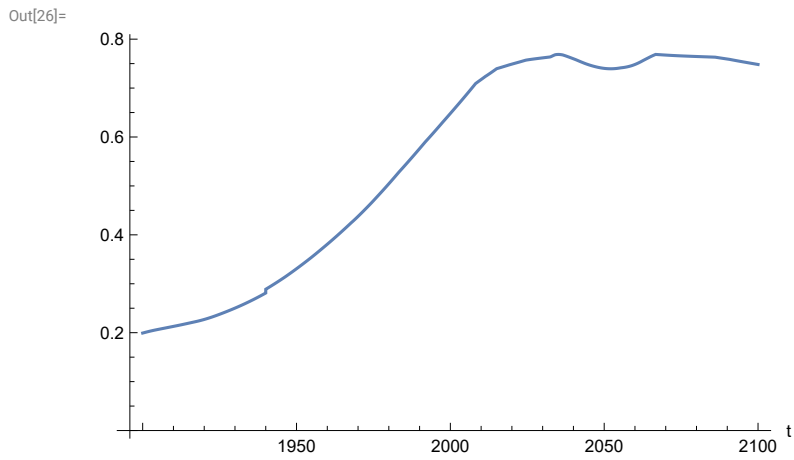
Out[24]=



In[25]=

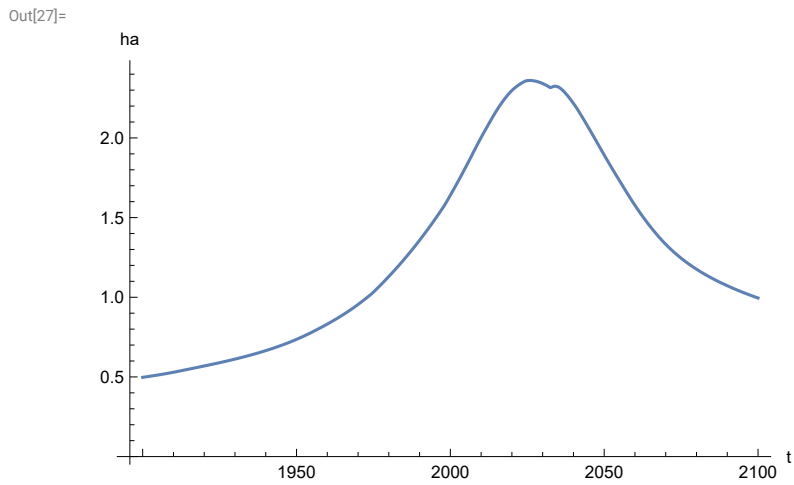
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

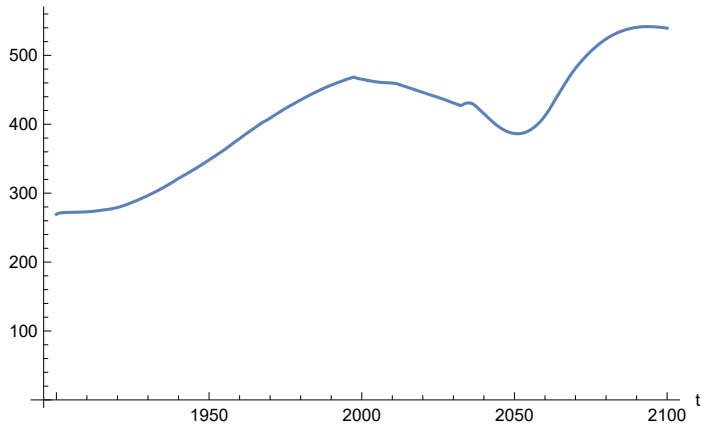
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

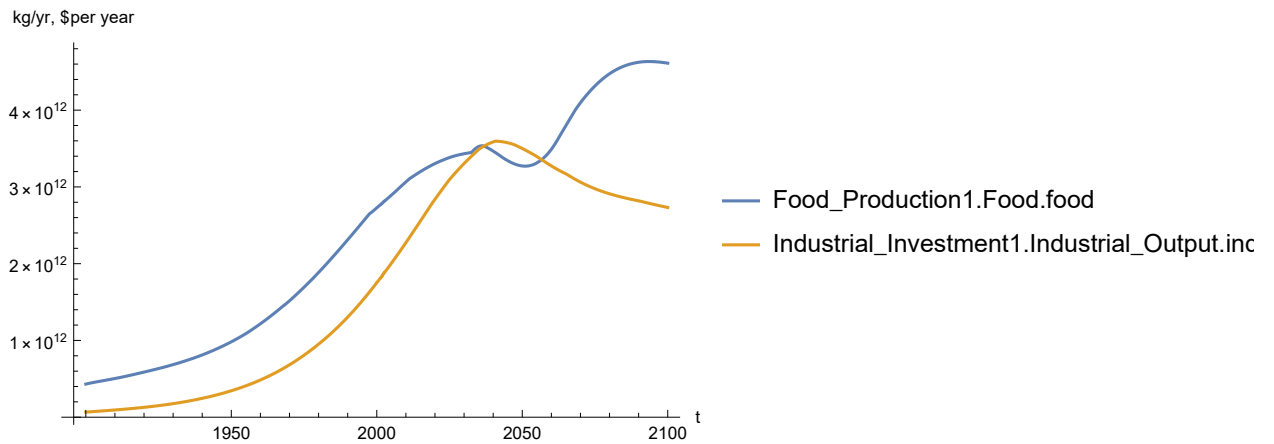
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

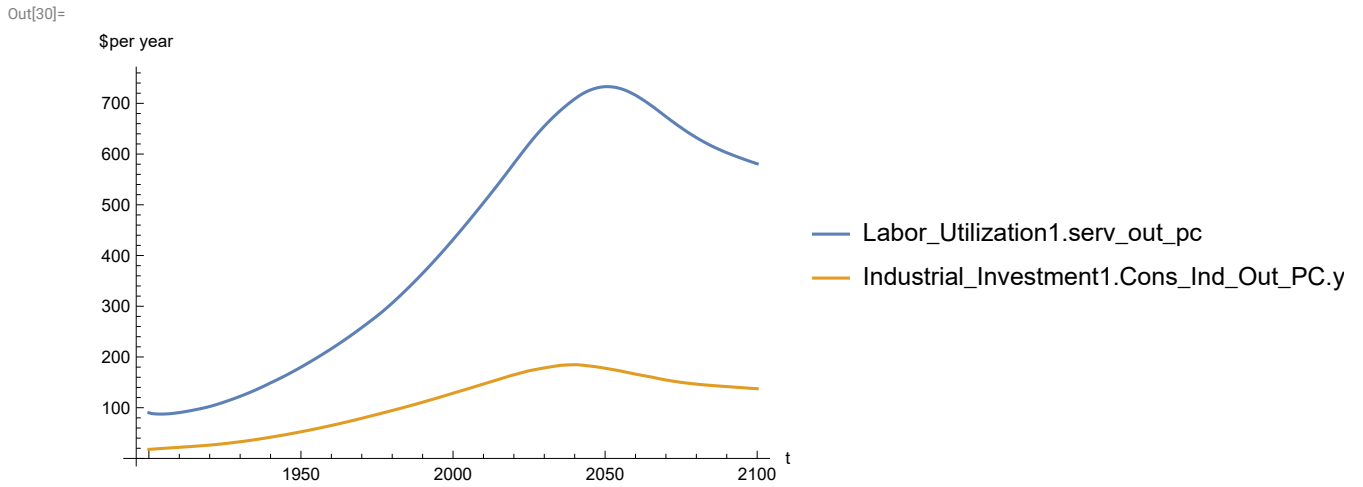
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

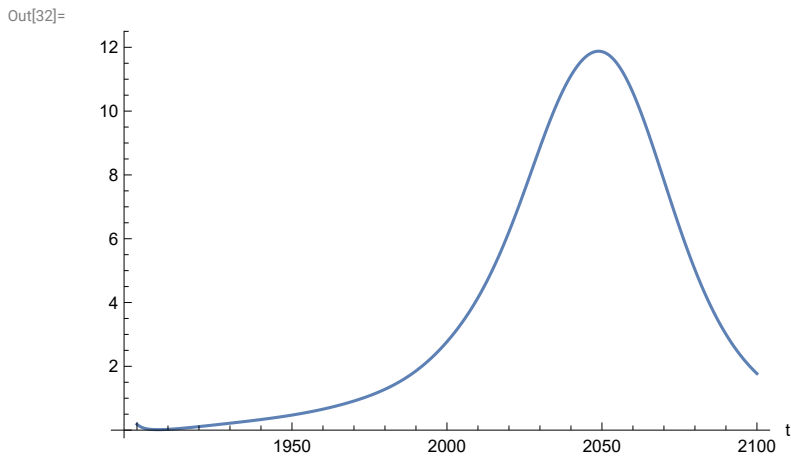


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 732.926
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

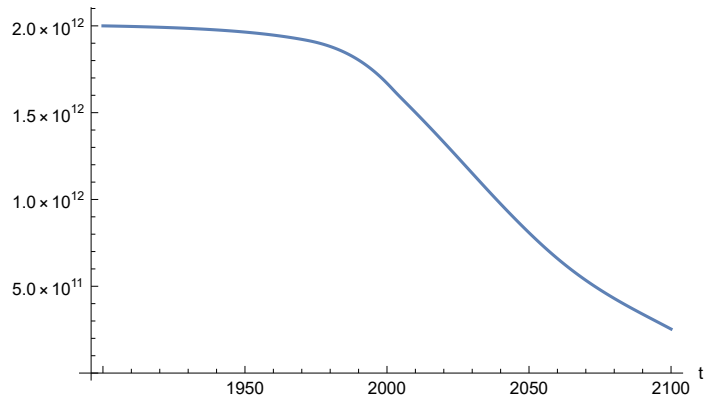


Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.8775
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[ ]=
```



APPENDIX 79. BENCHMARK SCENARIO 7, Experiment 79. $t_{policy_year} = 4000$.

Last modified: 30 July 2022/1120 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

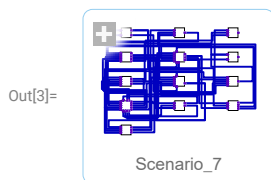
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

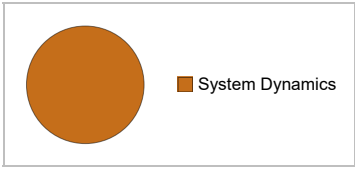
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Benchmark Scenario 7.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_7"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_7
	Description	More abundant non-recoverable natural resources and birth control
	Simulation Interval	True
	Policy Year	0
	Control Count	106
	Base Case	True
Out[4]=	Simulation Length	265
	Simulation Length	265
	Diagram	

Show the default value of `t_policy_year`.

```
In[5]:= SystemModel[mysim][{"ParameterValues", "t_policy_year"}]
```

```
Out[5]= {t_policy_year → 4000}
```

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

```
In[6]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[7]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[8]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[9]:= SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```


```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

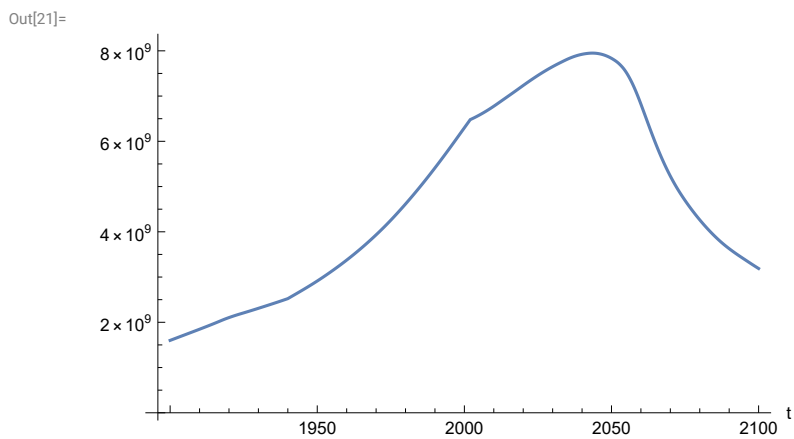
Execute scenario and plot various variables

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

```
Out[20]= SystemModelSimulationData [
   Model: Scenario_7
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

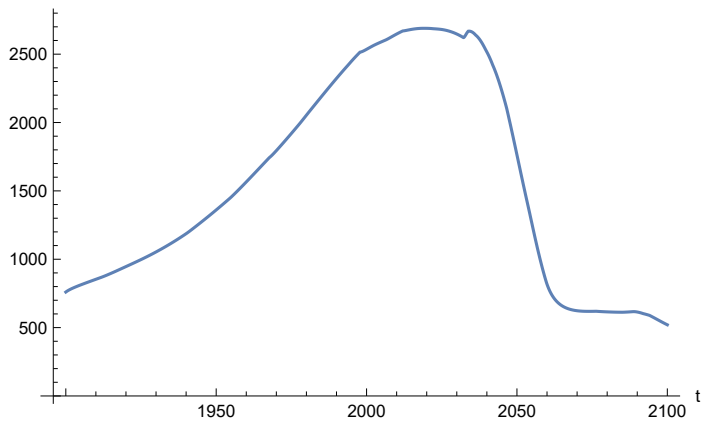
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.94948 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

Out[23]=



Find max and min of y values.

In[24]:= **MinAndMax**[basesim[{"Food_Production1.Land_Yield.y"}]]

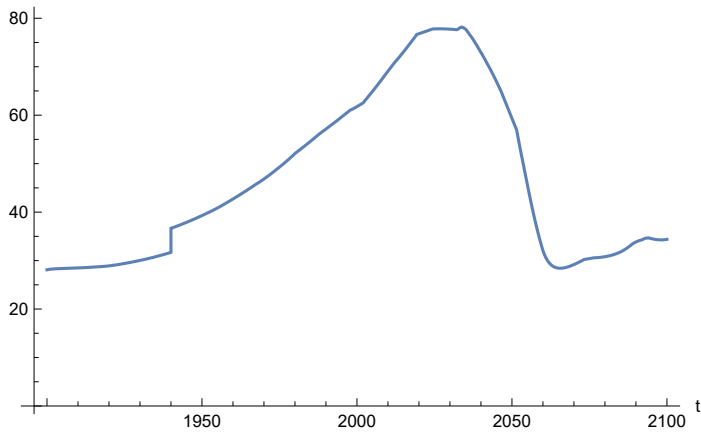
Maximum is 2689.02

Minimum is 520.413

Plot life expectancy, years.

In[25]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

Out[25]=

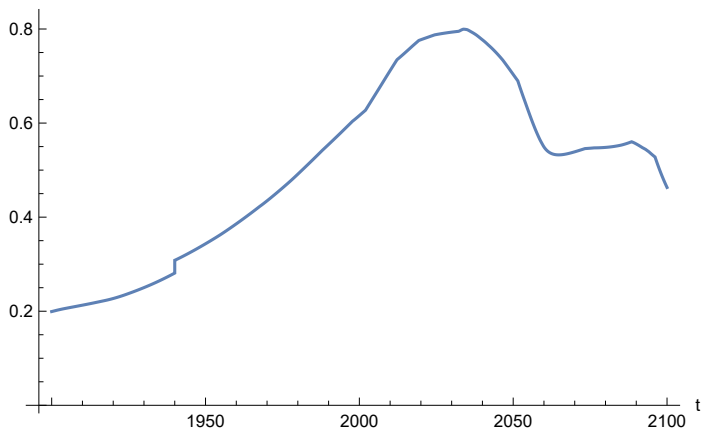


In[26]:=

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

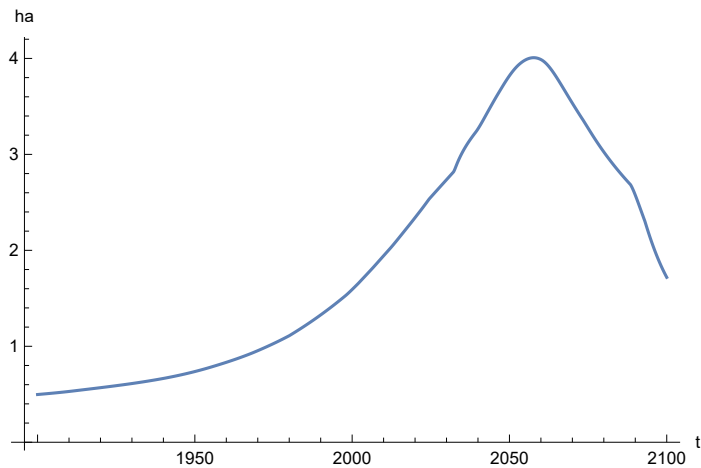
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```

Out[28]=



Find max and min of y values.

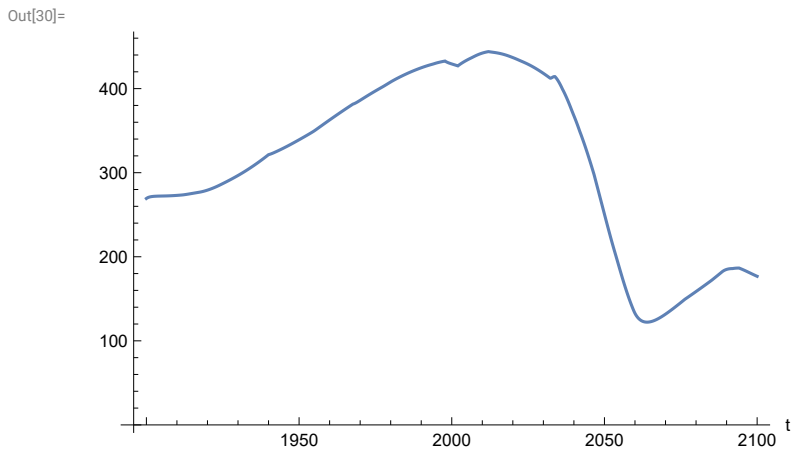
```
In[29]:= MinAndMax[basesim[
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]]
```

Maximum is 4.00761

Minimum is 0.497387

Plot food production per capita (kg/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Find max and min of y values.

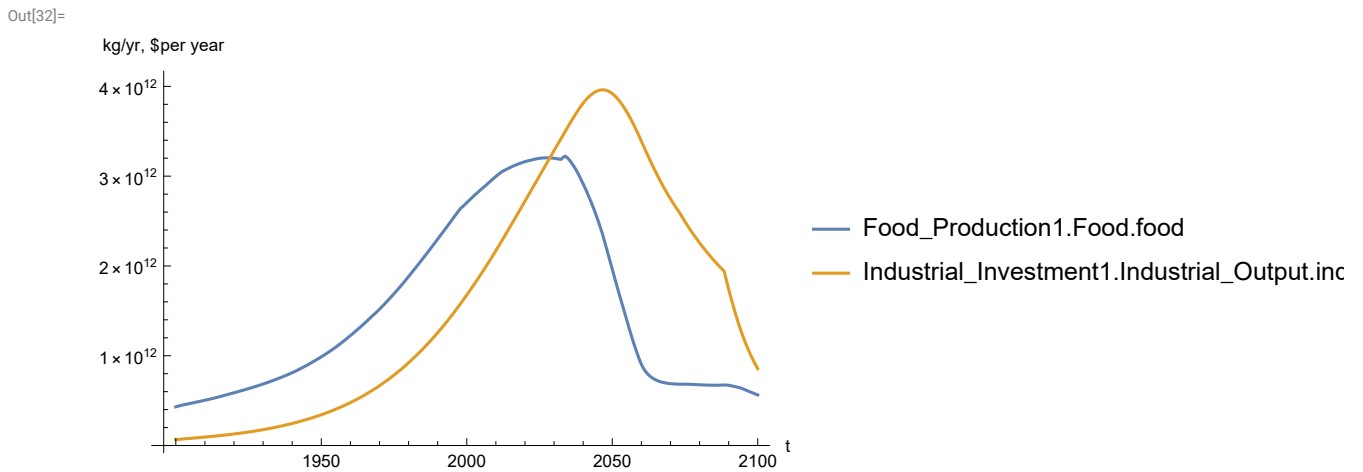
```
In[31]:= MinAndMax[basesim[{"Food_Production1.Food_PC.y"}]]
```

Maximum is 444.011

Minimum is 122.217

Plot total food production (kg/year), and industrial output (dollars/year).

```
In[32]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Industrial_Investment1.Industrial_Output.industrial_output"}]]
```

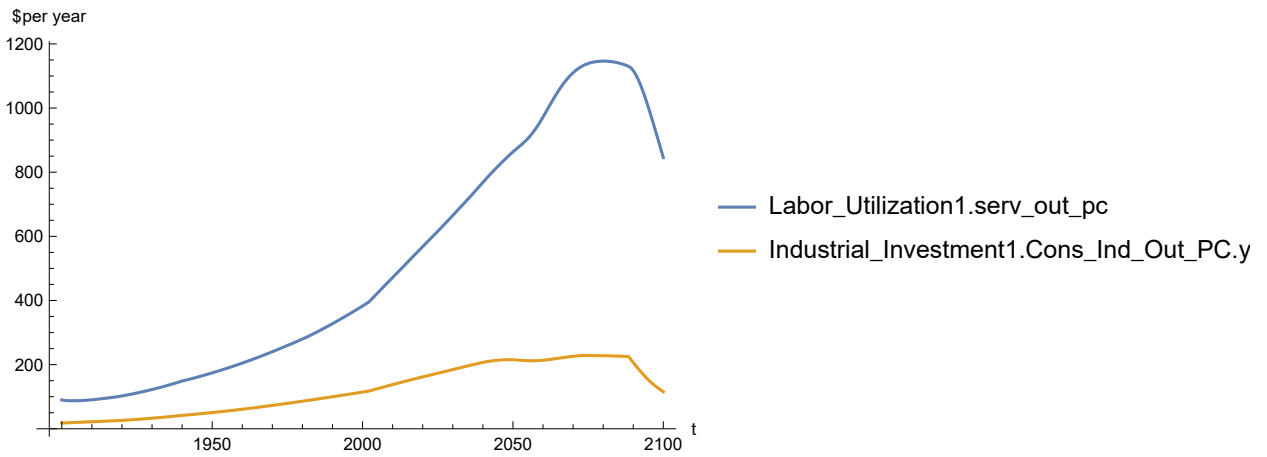
Maximum is 3.96115×10^{12}

Minimum is 6.65×10^{10}

Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[34]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[34]=



Find max and min of y values.

```
In[35]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1146.3
 Minimum is 87.4451

Find max and min of y values.

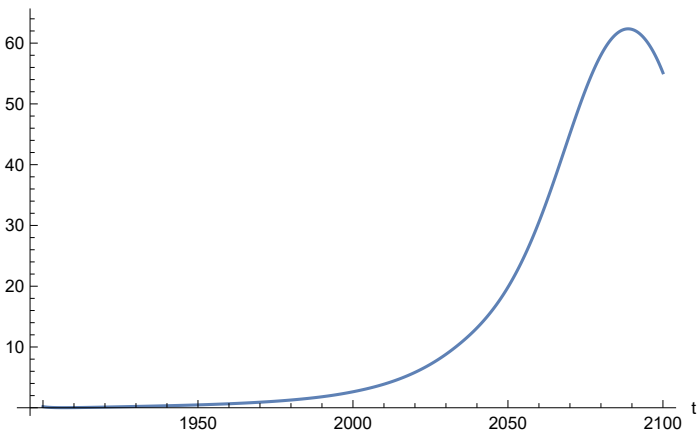
```
In[36]:= MinAndMax[basesim[{"Industrial_Investment1.Cons_Ind_Out_PC.y"}]]
```

Maximum is 228.786
 Minimum is 17.8719

Plot persistent pollution index.

```
In[37]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[37]=



Find max and min of y values.

```
In[38]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

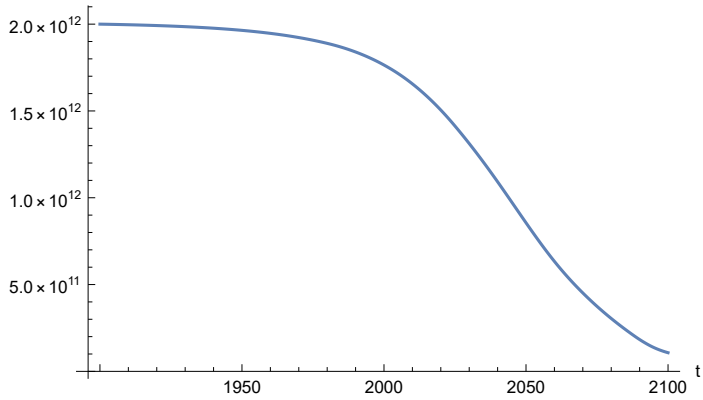
Maximum is 62.3495

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[39]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[39]=

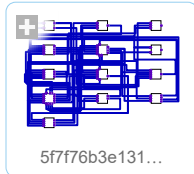


APPENDIX 80. $t_policy_year = 1970$, Benchmark Scenario 7, Experiment 80

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.

```
In[40]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[40]=
```



```
In[41]:= testsim1970 = SystemModelSimulate[newmysim1970]
```

```
Out[41]=
```

```
SystemModelSimulationData [ {  Model: W5f7f76b3e131411f9cdc4c0189b8a708  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  } ]
```

Show the value of t_policy_year .

```
In[42]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
```

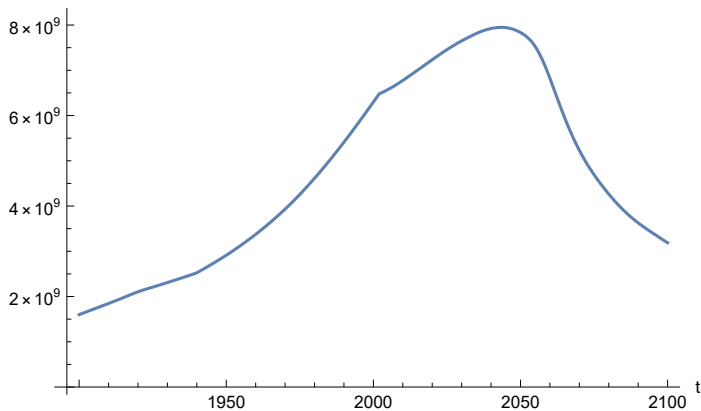
```
Out[42]=
```

```
{t_policy_year → 1970}
```

Plot the world population, people.

```
In[43]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
```

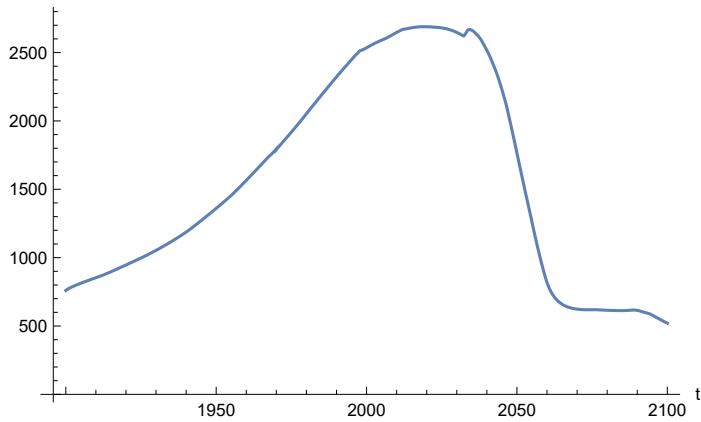
```
Out[43]=
```



Find max and min of y values.

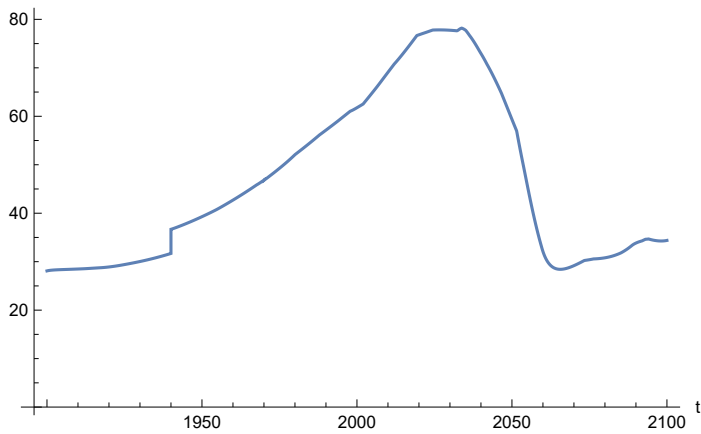
```
In[44]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.94897 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[45]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
Out[45]=
```



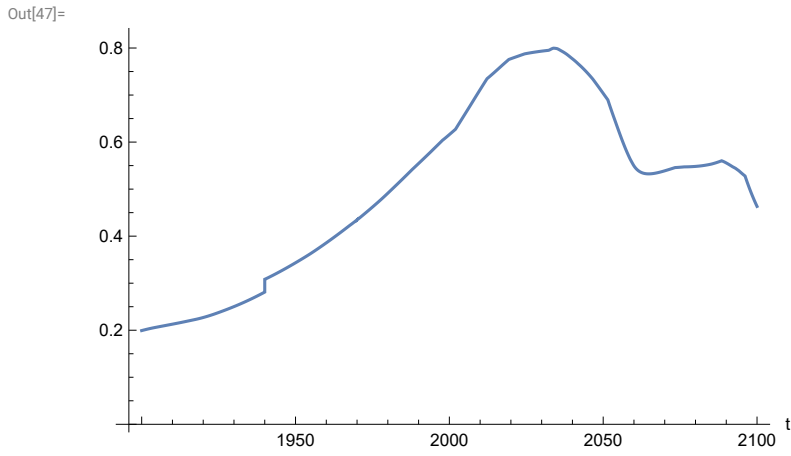
Plot life expectancy, in years.

```
In[46]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[46]=
```



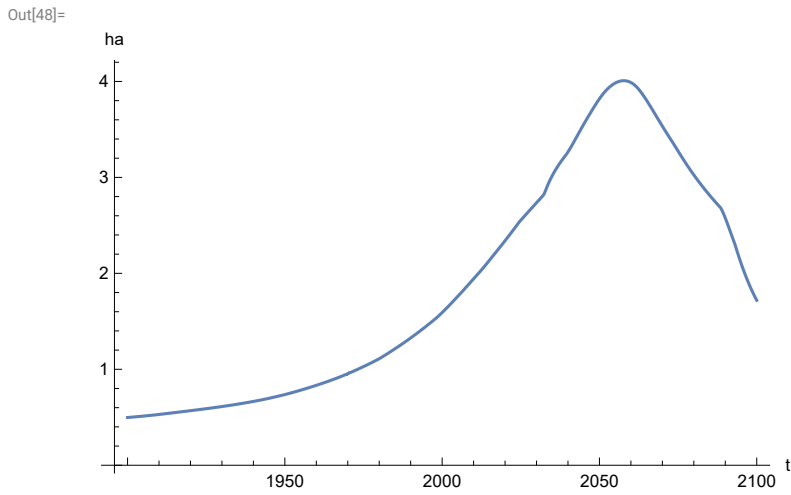
Plot the human welfare index.

```
In[47]:= SystemModelPlot[testsim1970,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



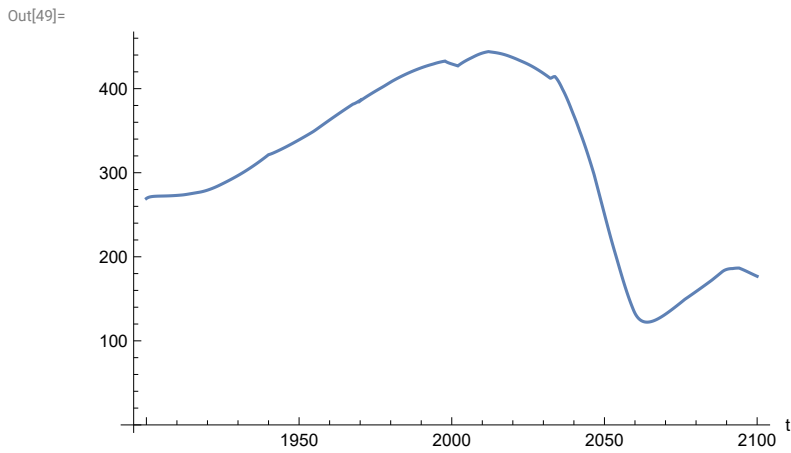
Plot the human ecological footprint, in hectares.

```
In[48]:= SystemModelPlot[testsim1970,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



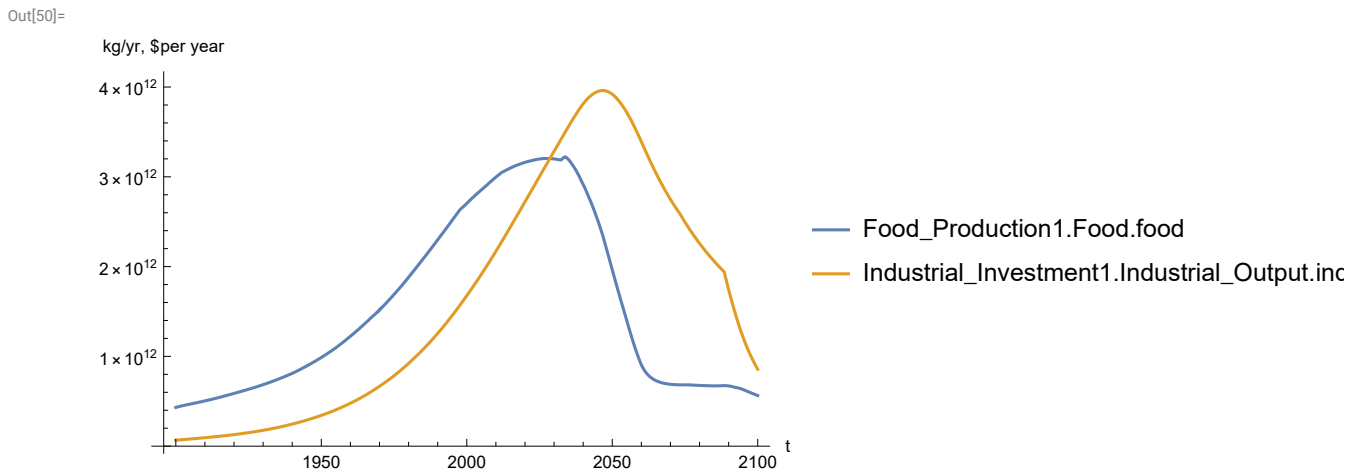
Plot per capita food production, kg/year.

In[49]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]**



Plot total food production (kg/yr) and industrial output (in dollars).

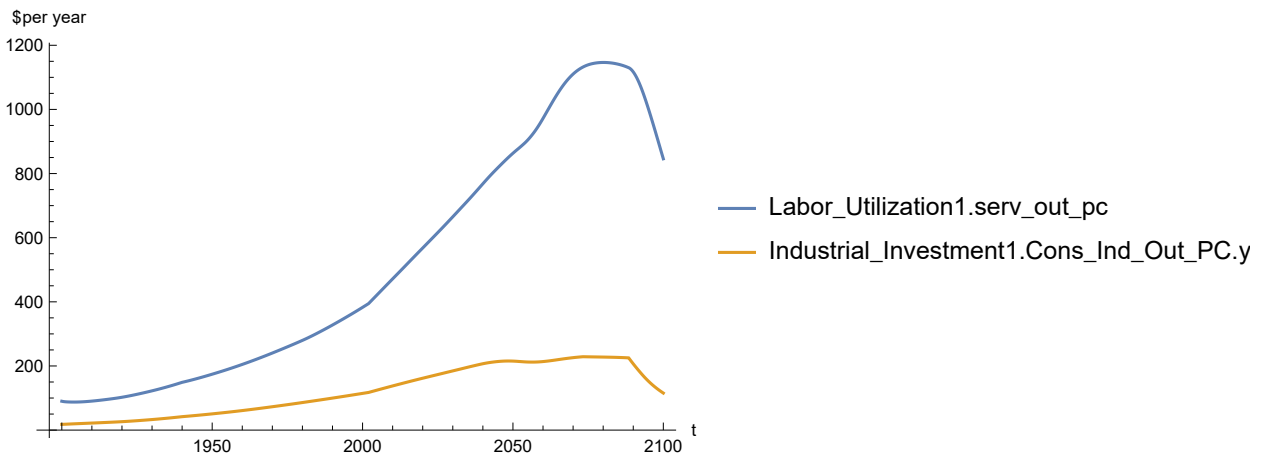
In[50]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[51]:= SystemModelPlot[testsim1970,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[51]=



Find max and min of y values.

```
In[52]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

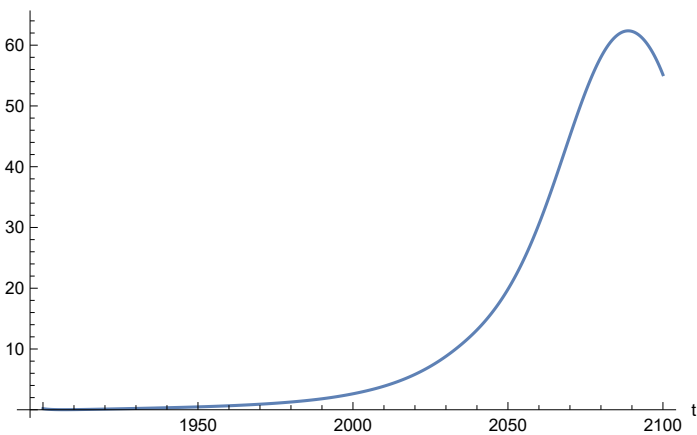
Maximum is 1146.44

Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[53]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[53]=



Find max and min of y values.

```
In[54]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

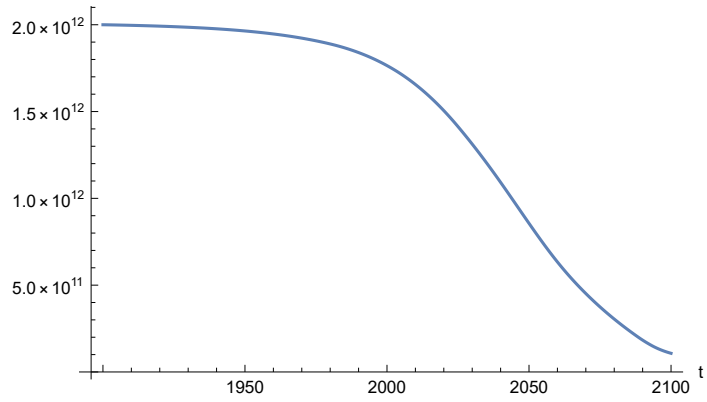
Maximum is 62.3581

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[55]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[55]=

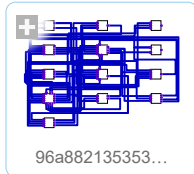


APPENDIX 81. Benchmark Scenario 7, `t_policy_year = 2025`. Experiment 81.

Change time `t_policy_year` to 2025, and execute the resulting scenario, plotting various variables

```
In[56]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
```

```
Out[56]=
```



```
In[57]:= testsim = SystemModelSimulate[newmysim]
```

```
Out[57]=
```

```
SystemModelSimulationData [ Model: W96a882135353490b8351316114fc7eab  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of `t_policy_year`.

```
In[58]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
```

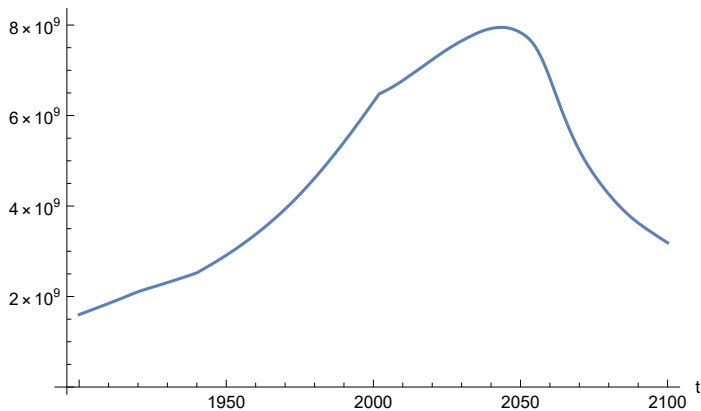
```
Out[58]=
```

```
{t_policy_year → 2025}
```

Plot the world population, people.

```
In[59]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[59]=
```

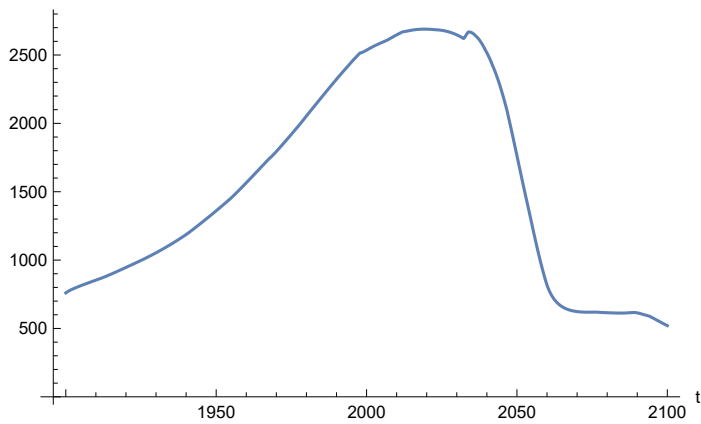


Find max and min of y values.

```
In[60]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.94948 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

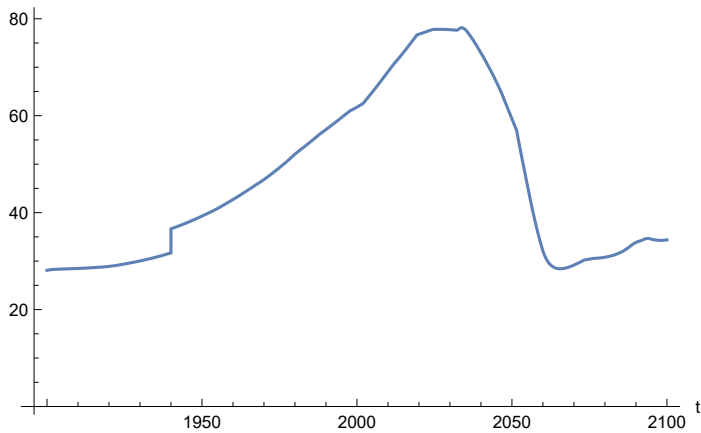
Plot land yield.

```
In[61]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[61]=
```



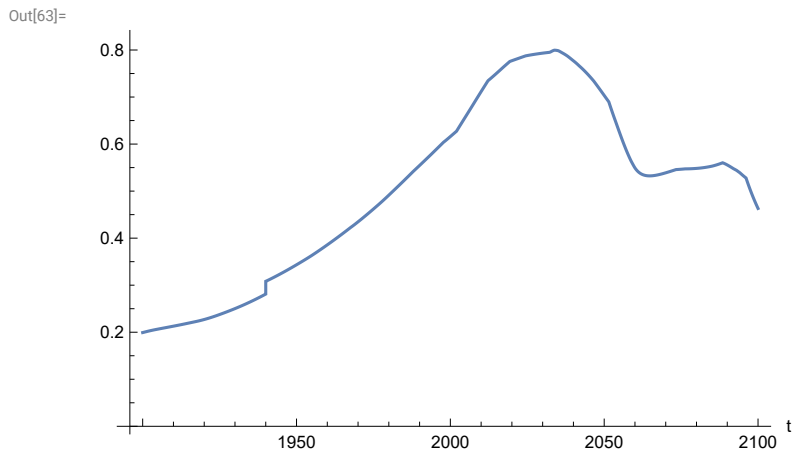
Plot life expectancy, in years.

```
In[62]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[62]=
```



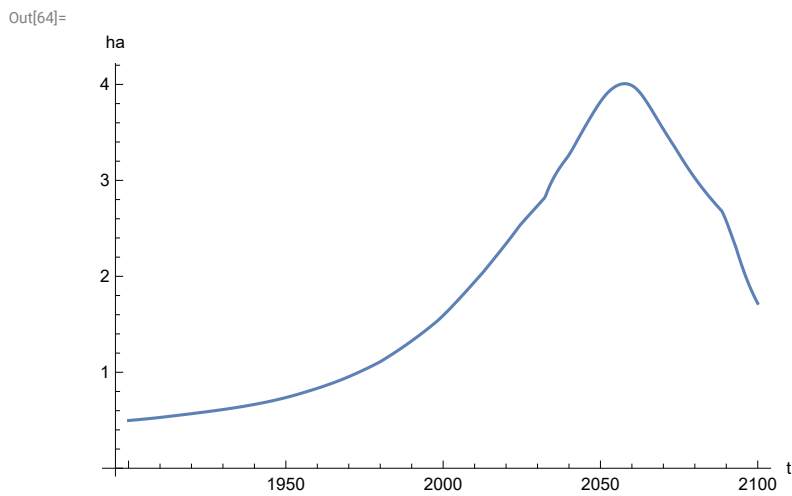
Plot the human welfare index.

```
In[63]:= SystemModelPlot[testsim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



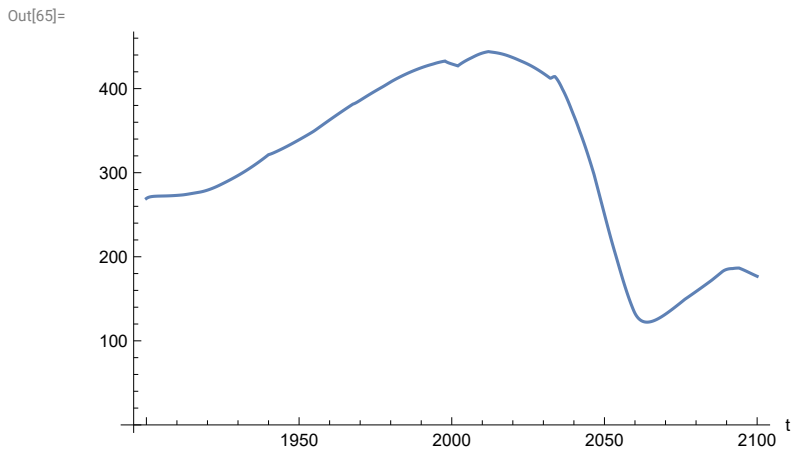
Plot the human ecological footprint, in hectares.

```
In[64]:= SystemModelPlot[testsim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



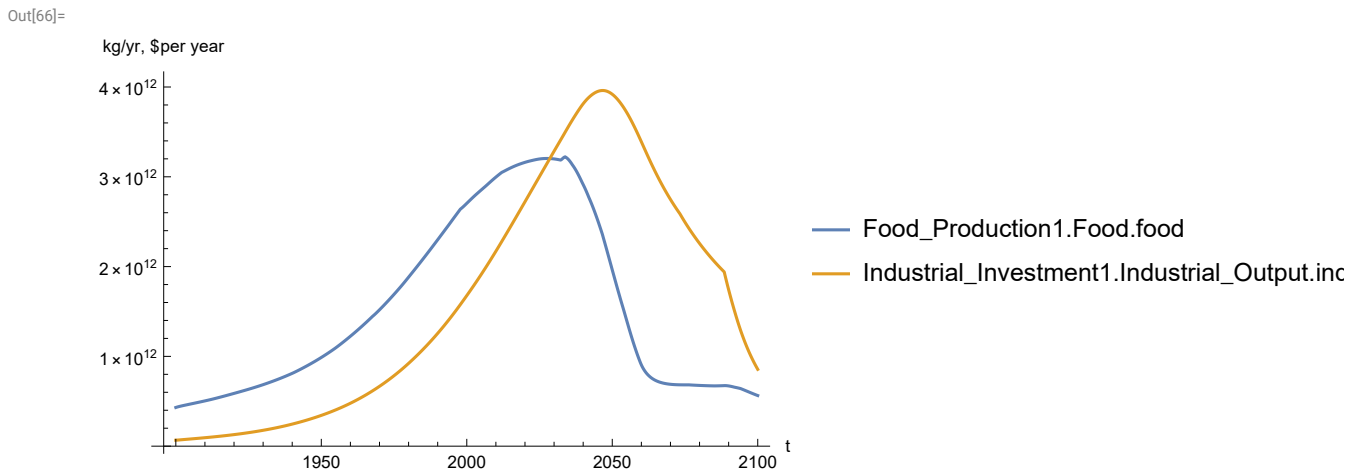
Plot per capita food production, kg/year.

In[65]:= **SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]**



Plot total food production (kg/yr) and industrial output (in dollars).

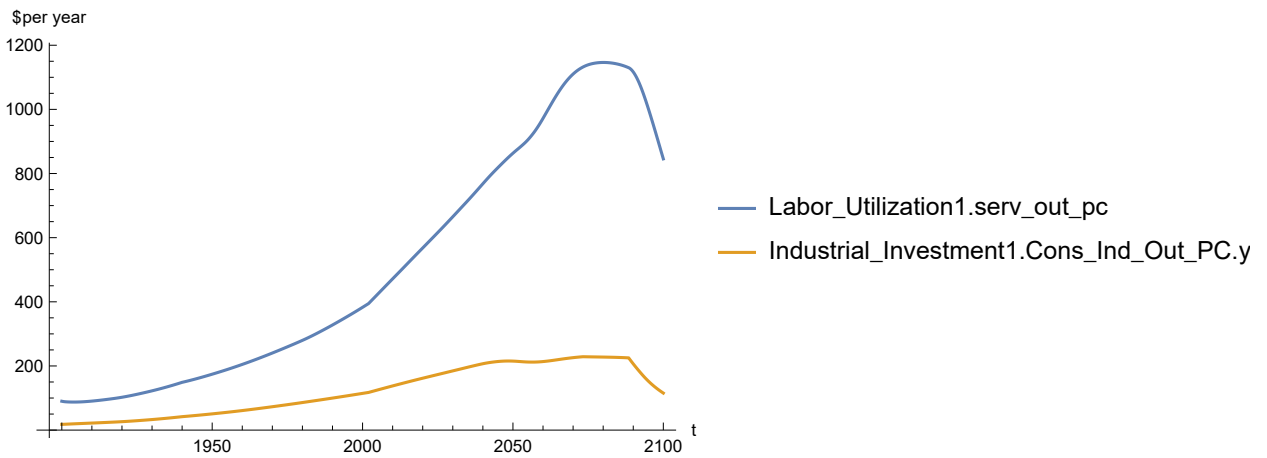
In[66]:= **SystemModelPlot[testsim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**



Plot consolidated industrial output per capita (dollars/year).

```
In[67]:= SystemModelPlot[testsim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[67]=



Find max and min of y values.

```
In[68]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
```

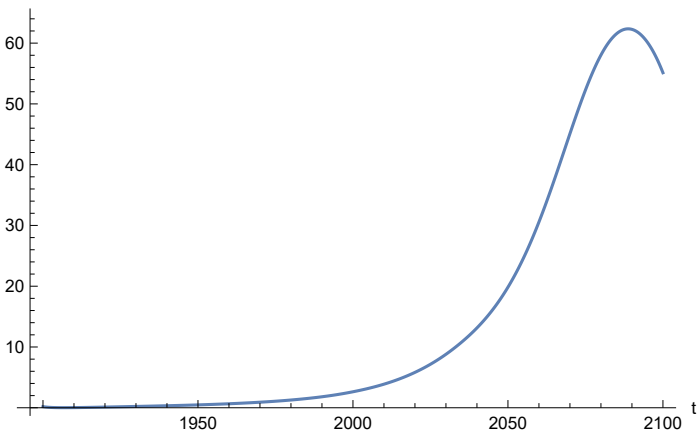
Maximum is 1146.3

Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[69]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[69]=



Find max and min of y values.

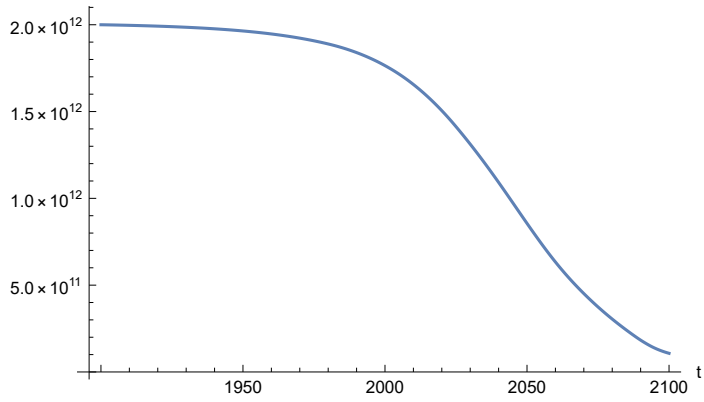
```
In[70]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 62.3495

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[71]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[71]=
```



APPENDIX 82. BENCHMARK SCENARIO 7, Experiment 82. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 30 July 2022/1135 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

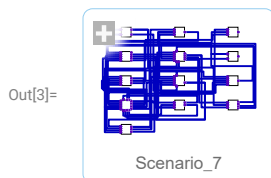
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

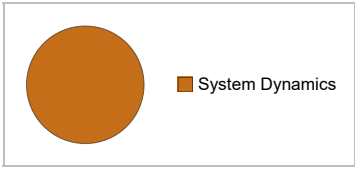
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 7.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_7"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_7
	Description	More abundant non-recoverable natural resources and birth control
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

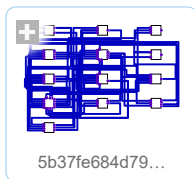
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

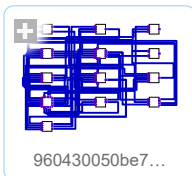
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

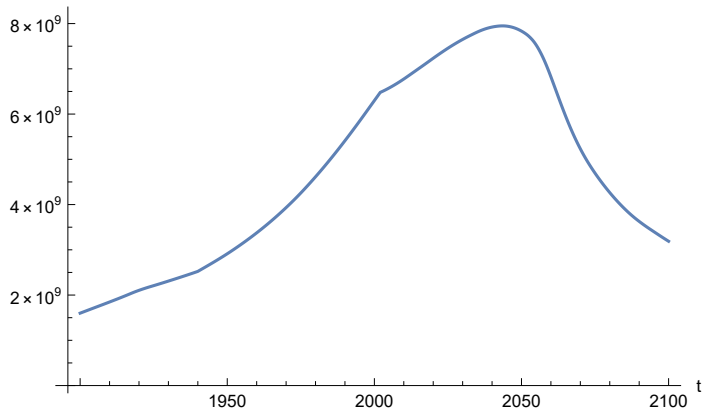
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W960430050be74f46ac10c67e8c55dcfe  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

In[22]:= **SystemModelPlot**[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]

Out[22]=



Find max and min of population values.

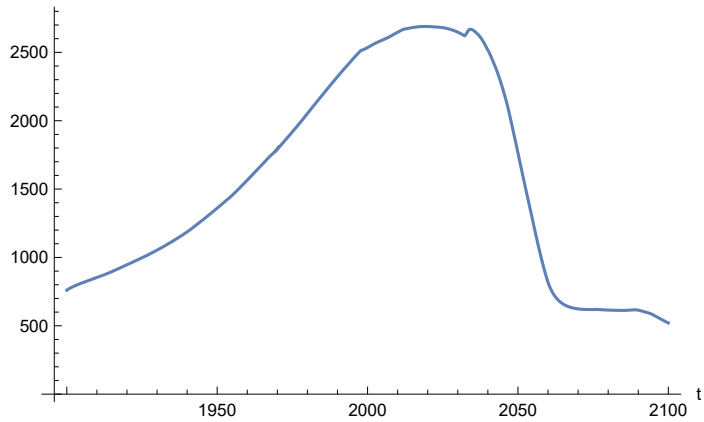
In[23]:= **MinAndMax**[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]

Maximum is 7.94897×10^9

Minimum is 1.6×10^9

In[24]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

Out[24]=



Plot life expectancy, years.

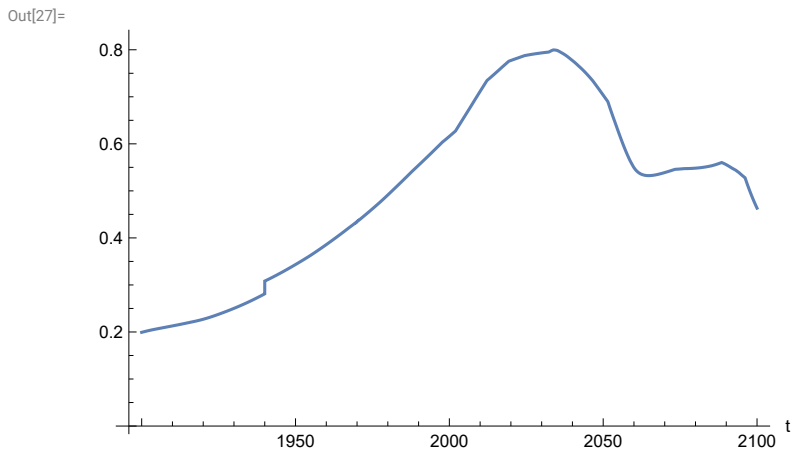
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[26]:=
```

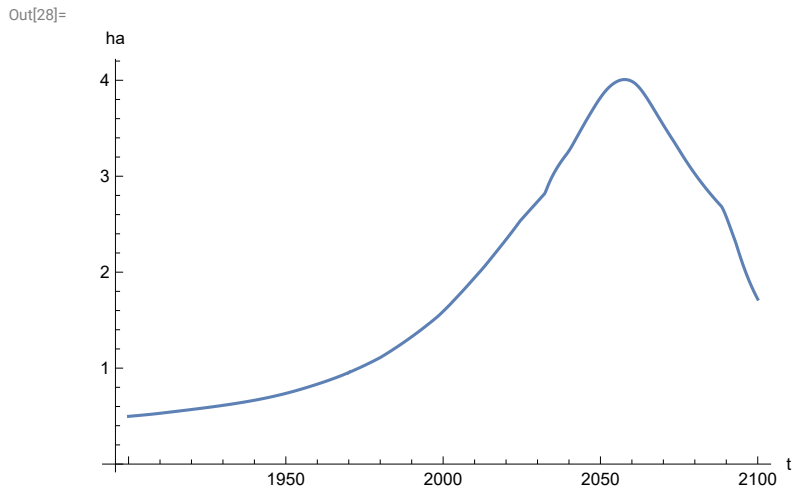
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

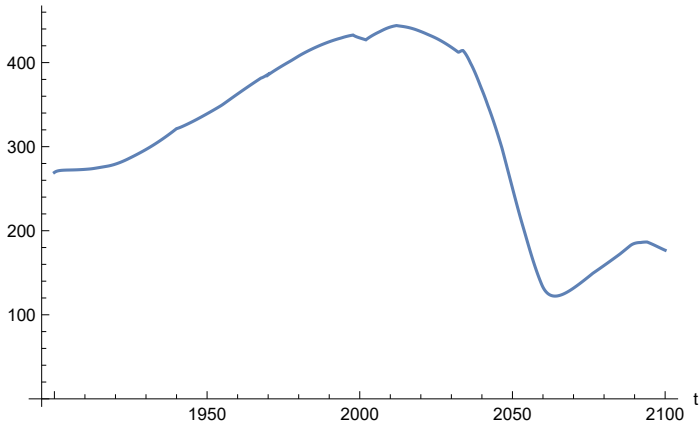
```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

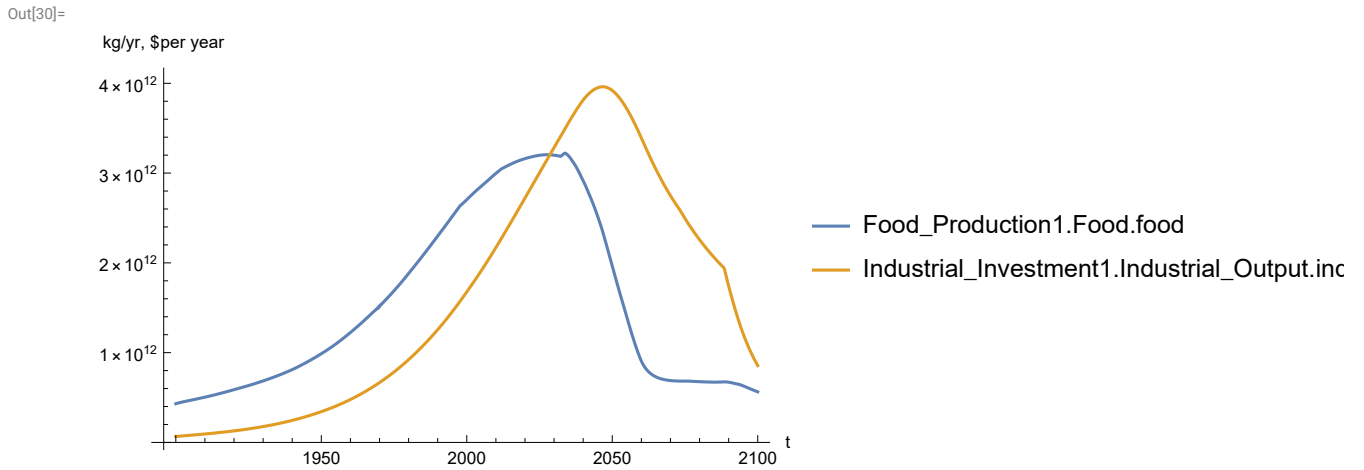
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[29]=



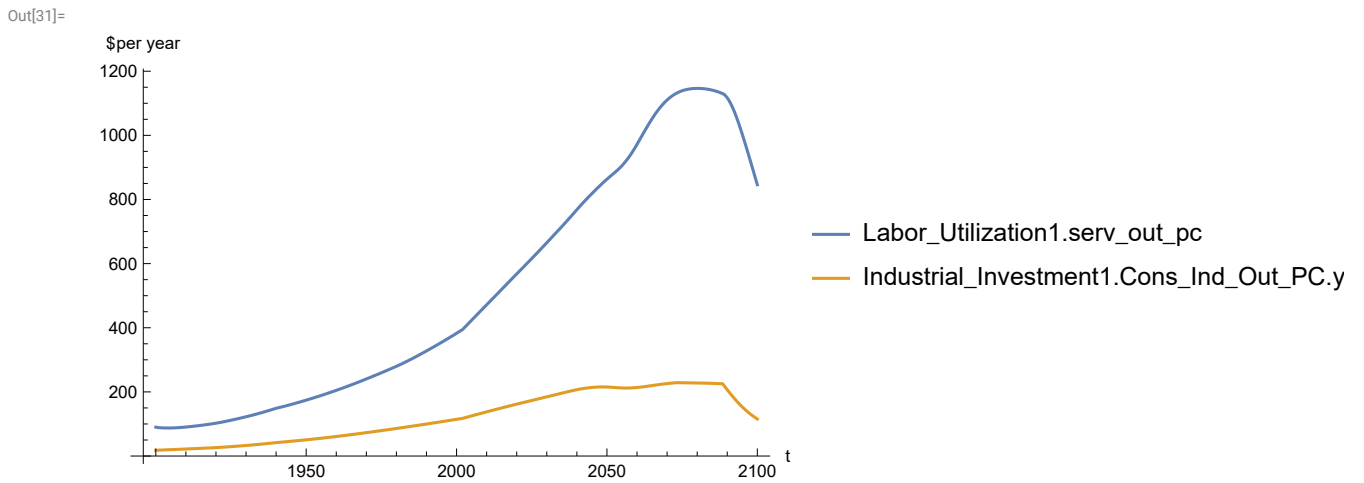
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
    {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

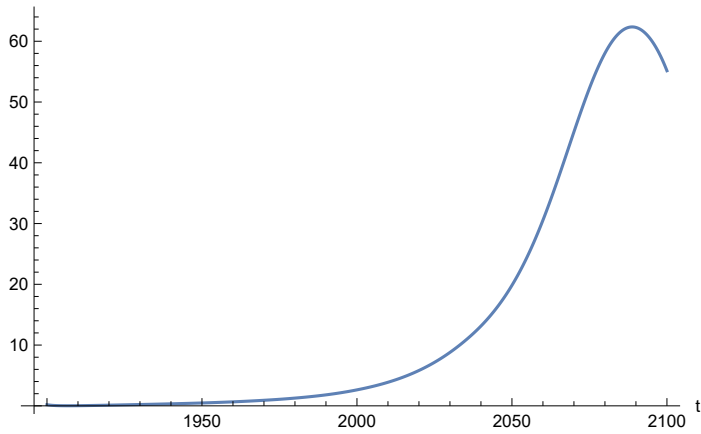
Maximum is 1146.44

Minimum is 87.4451

Plot persistent pollution index.

In[33]:= **SystemModelPlot**[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]

Out[33]=



Find max and min of y values.

In[34]:= **MinAndMax**[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]

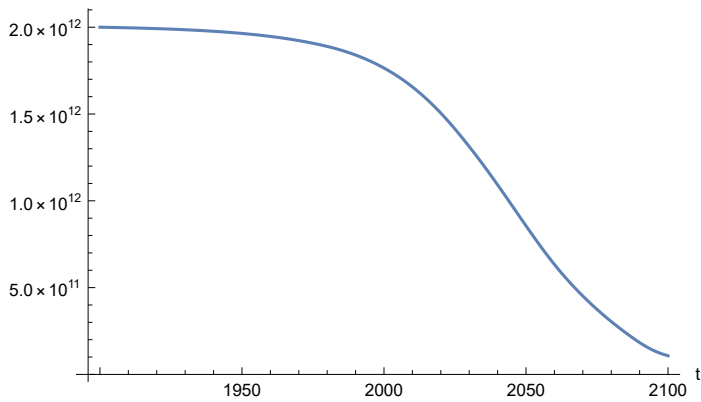
Maximum is 62.3581

Minimum is 0.0150765

Plot non-renewable resources remaining.

In[35]:= **SystemModelPlot**[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]

Out[35]=

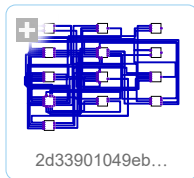


APPENDIX 83. LE/1.001, t_policy_year = 2025. Baseline Scenario 7, Experiment 83.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure default _Serv_2.y_vals

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

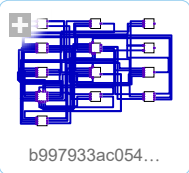
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```

Out[44]=  b997933ac054...

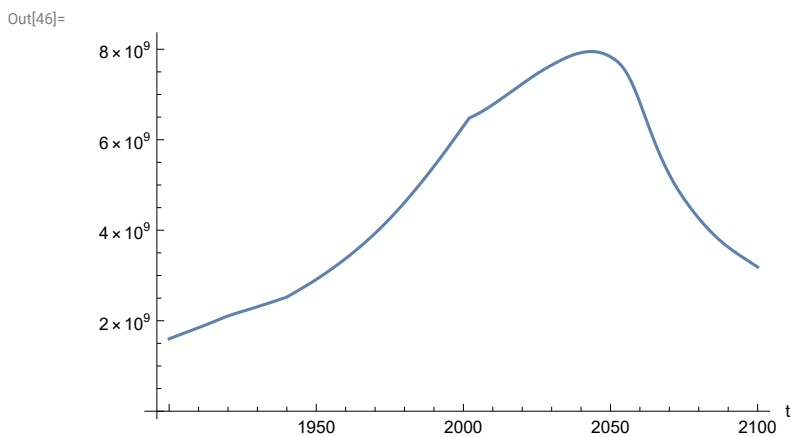
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: Wb997933ac0544468b83ffb9d78209754
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

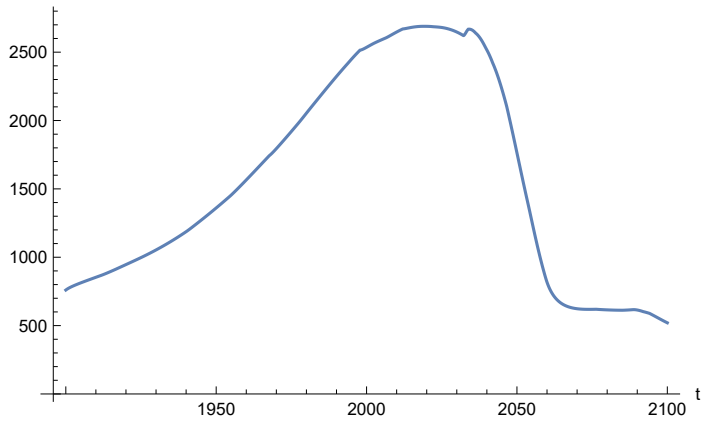
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.94948×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

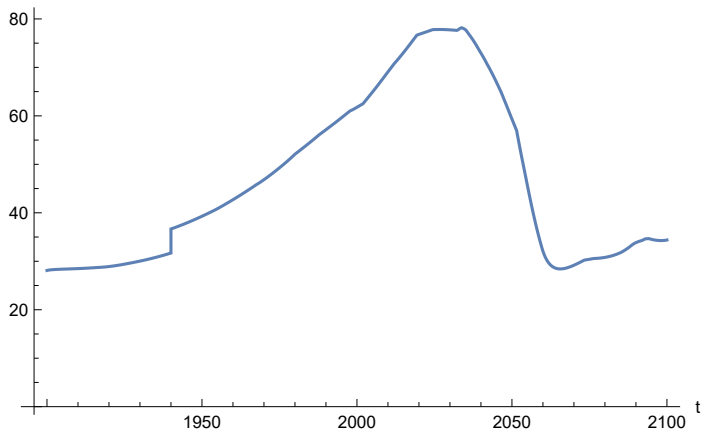
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

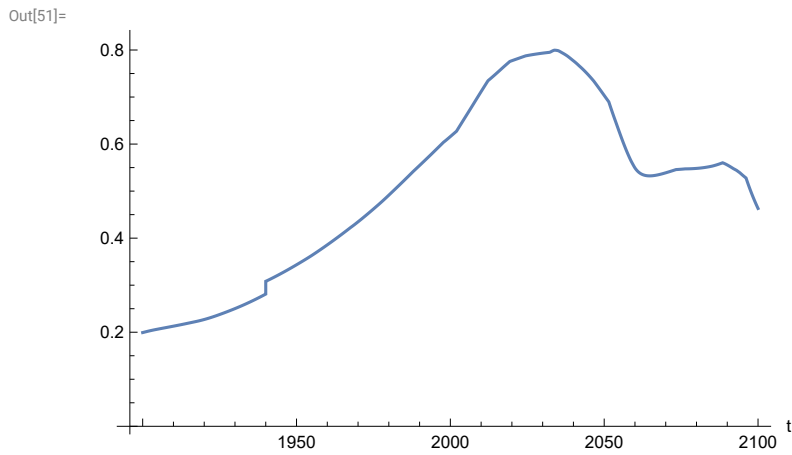
Out[49]=



In[50]:=

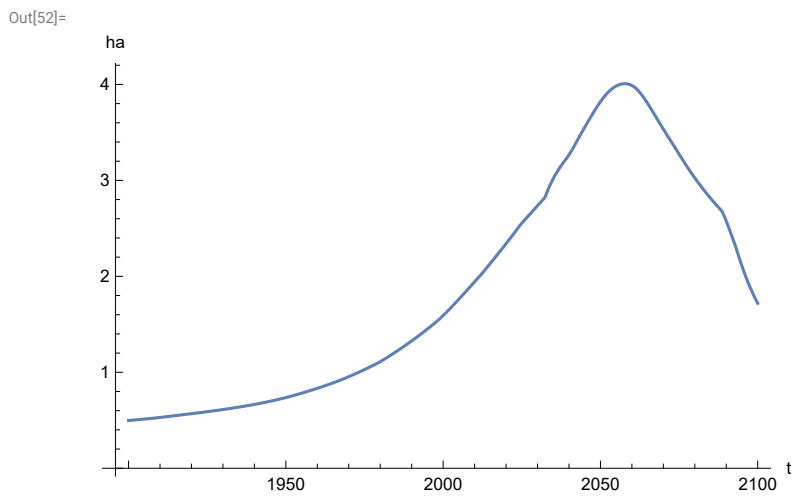
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

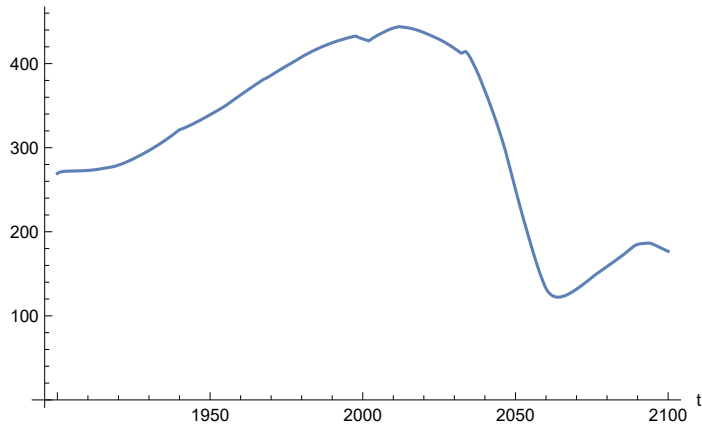
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

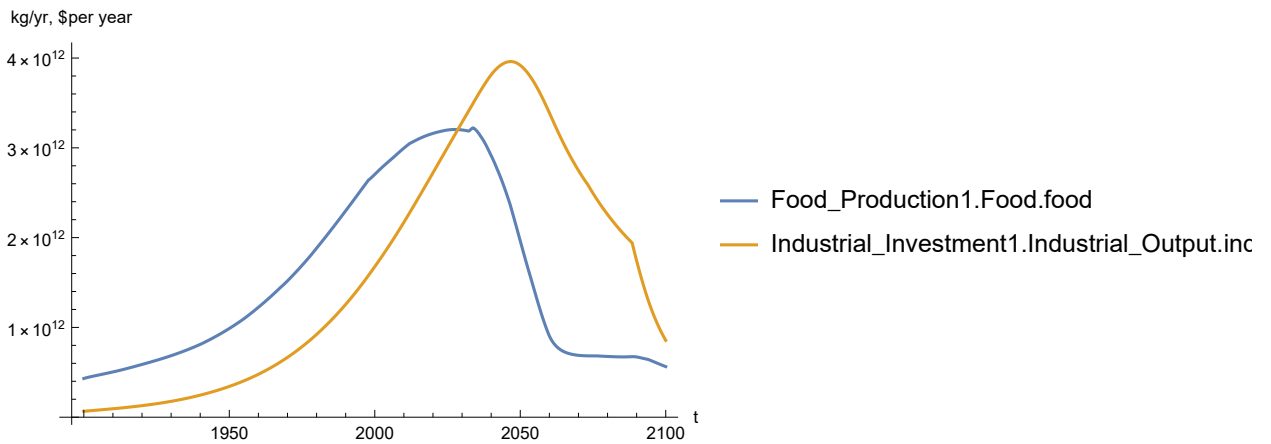
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

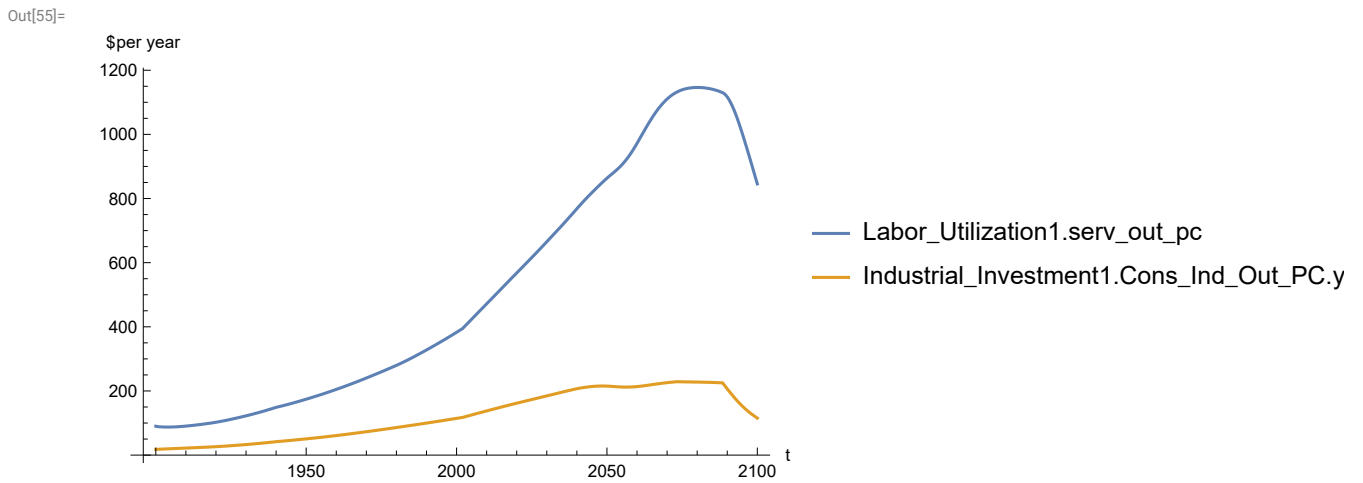
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



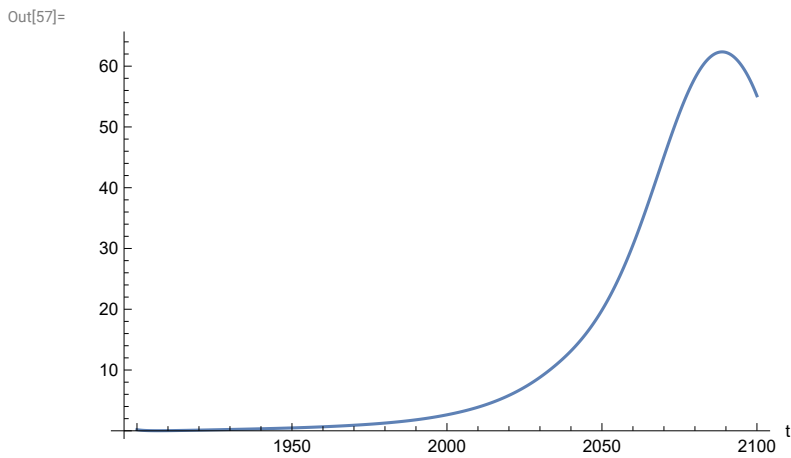
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1146.3
 Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

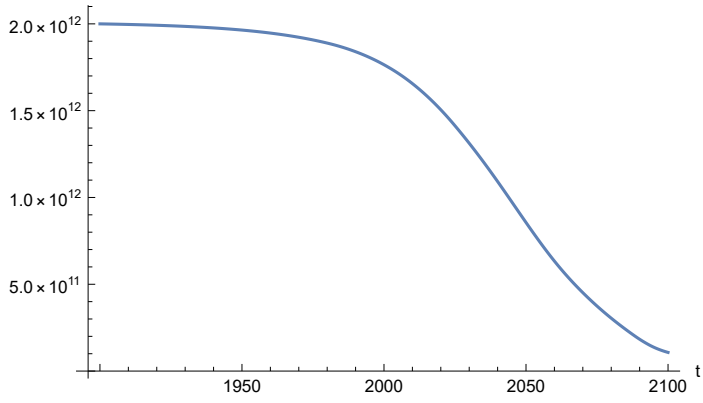
```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 62.3495
 Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

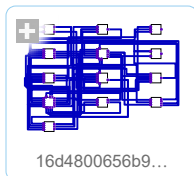


APPENDIX 84. LE/1.01, t_policy_year = 1970. Baseline Scenario 7, Experiment 84.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

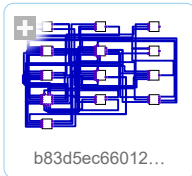
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

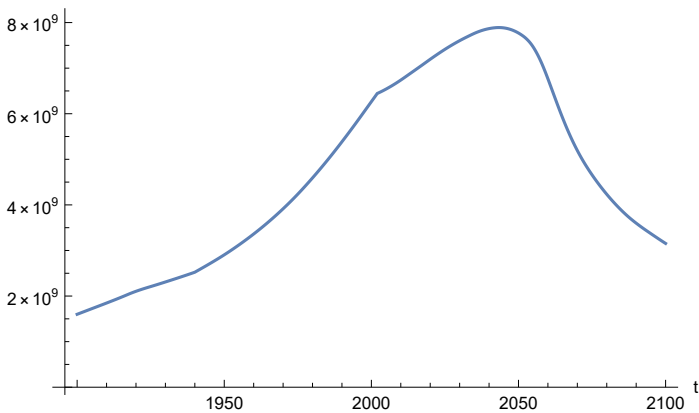
```
Out[69]=
```

```
SystemModelSimulationData [ Model: Wb83d5ec6601242009e2301d2bad73eb3
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

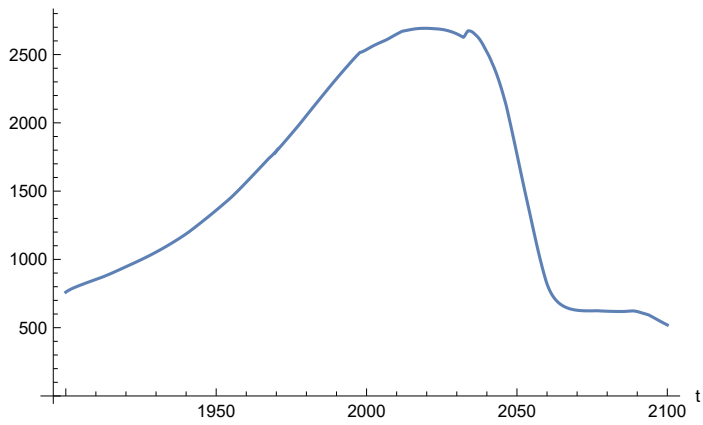
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.89069 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

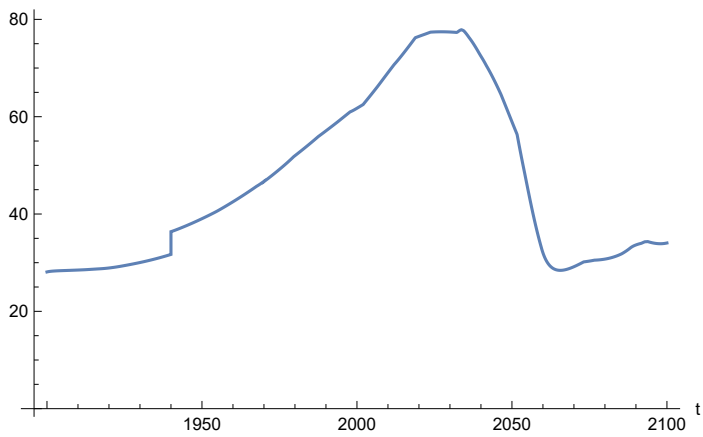
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

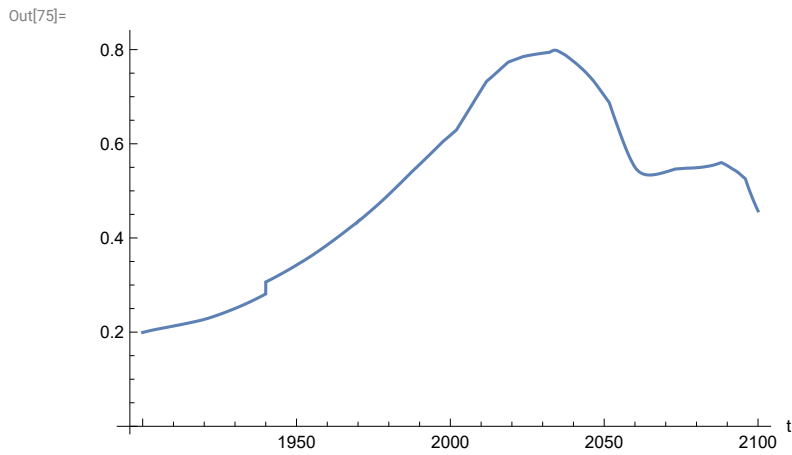
Out[73]=



In[74]:=

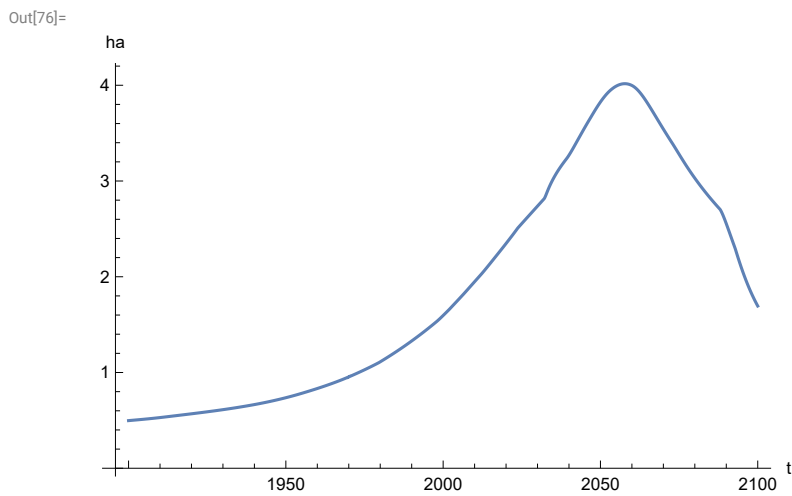
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

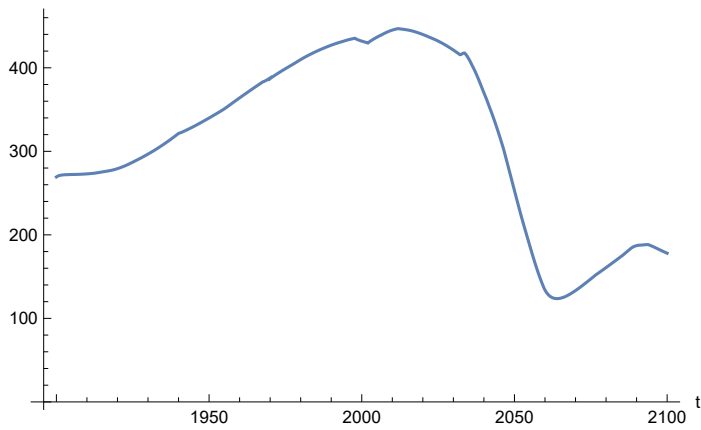
```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[77]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

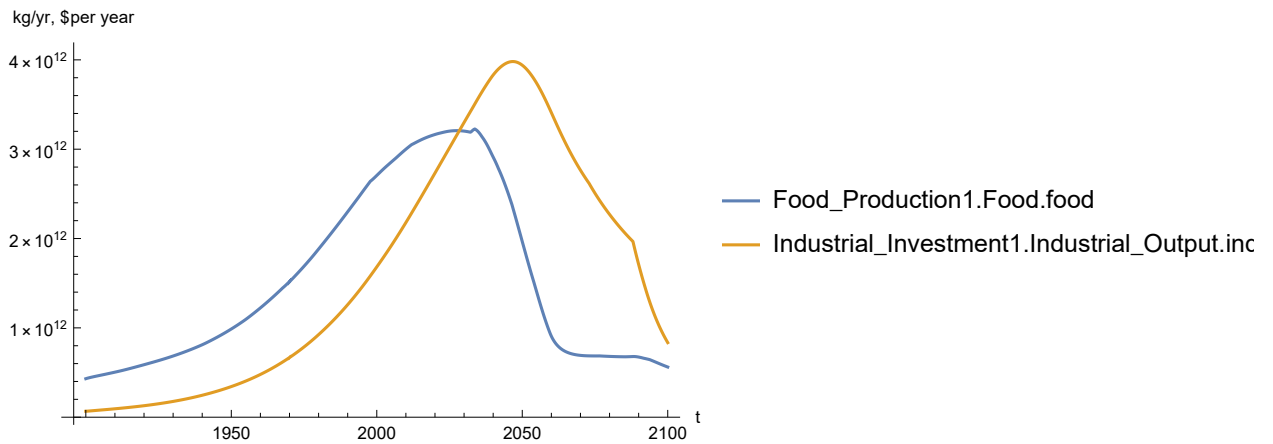
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[78]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

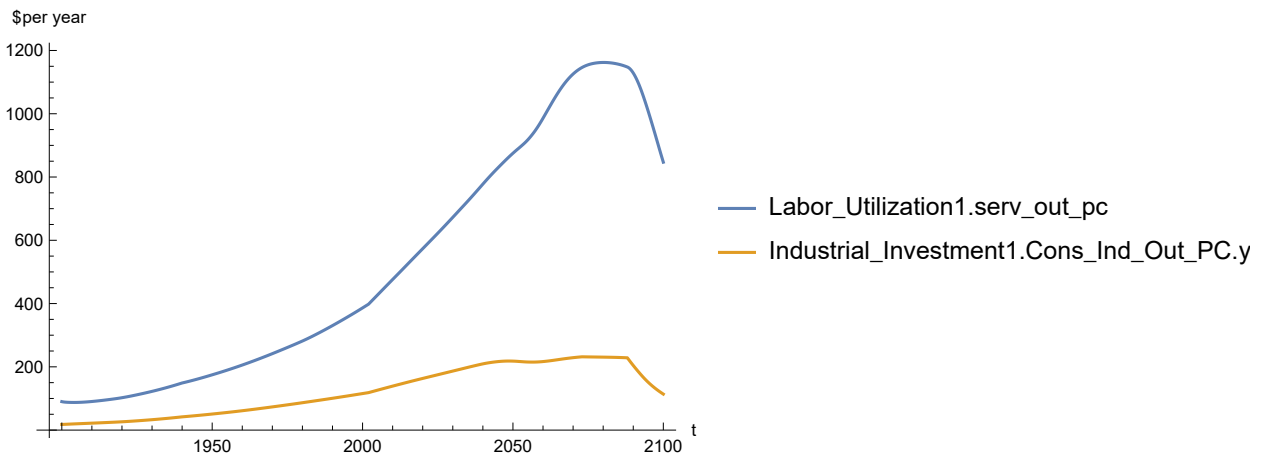
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

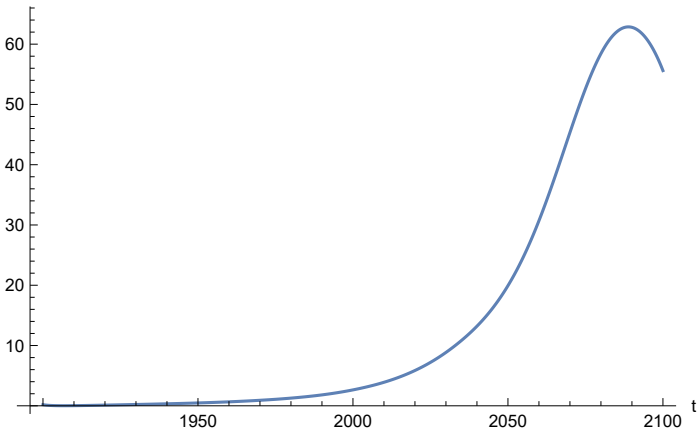
Maximum is 1162.14

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

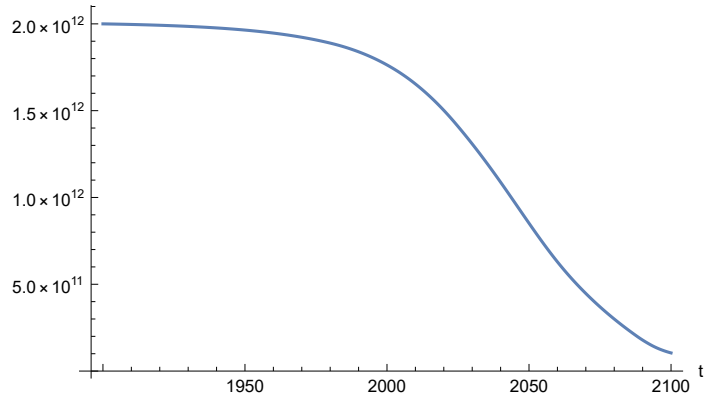
Maximum is 62.8659

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

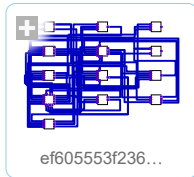
Out[83]=



APPENDIX 85. Baseline Scenario 7, Experiment 85. LE = LE/1.01, t_policy_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

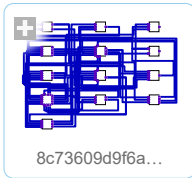
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

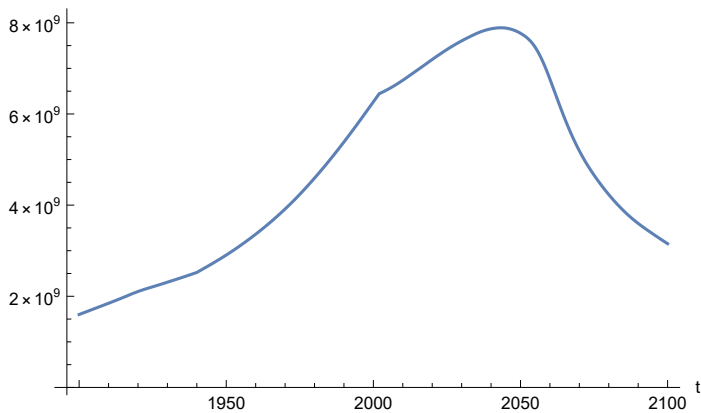
```
Out[93]=
```

```
SystemModelSimulationData [  Model: W8c73609d9f6a4e119b09afa28bd9c84a  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[94]=
```



Find max and min of population values.

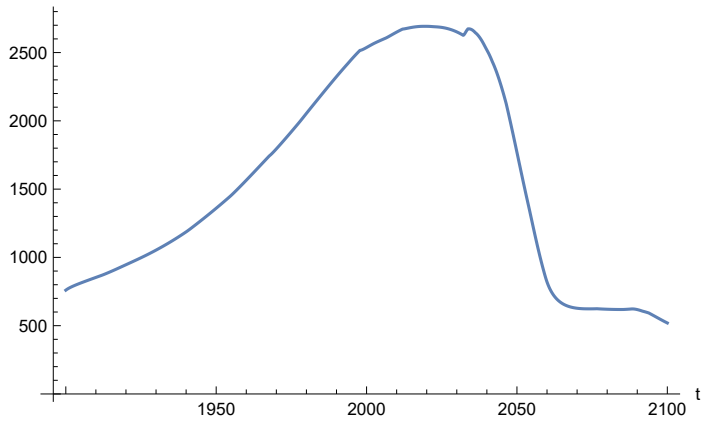
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.8912 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

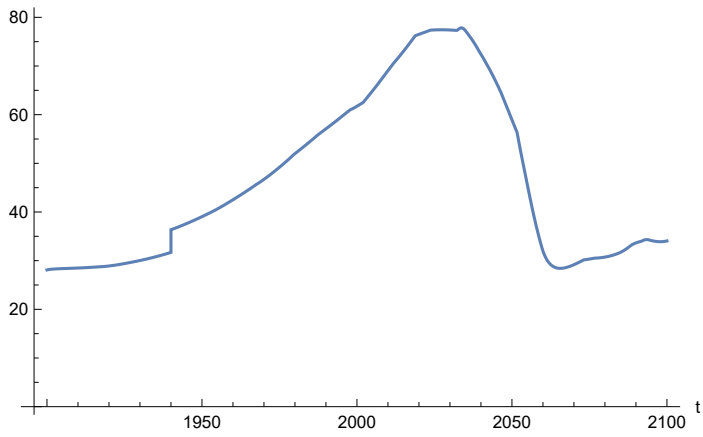
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

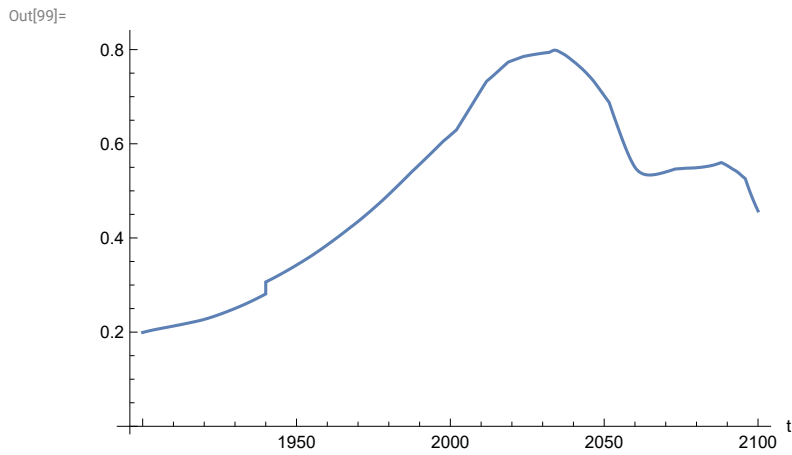
Out[97]=



In[98]:=

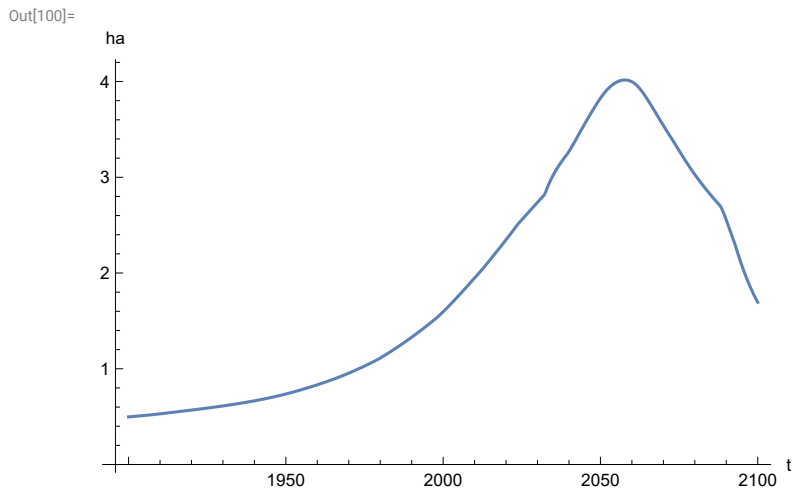
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



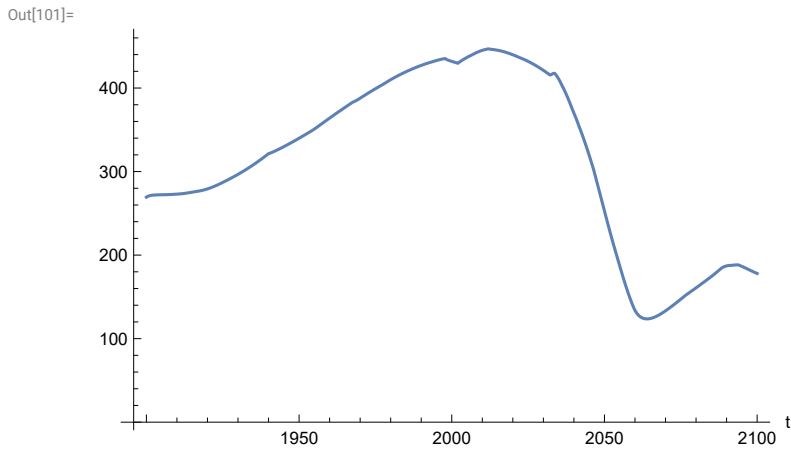
Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



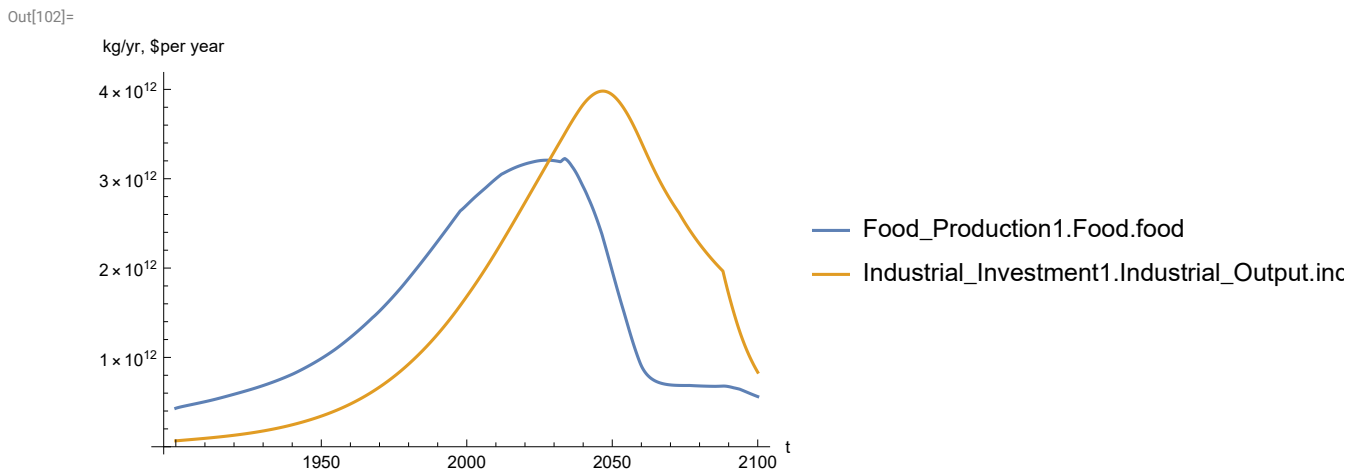
Plot food production per capita (kg/year).

```
In[101]:=
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[102]:=
SystemModelPlot[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]
```

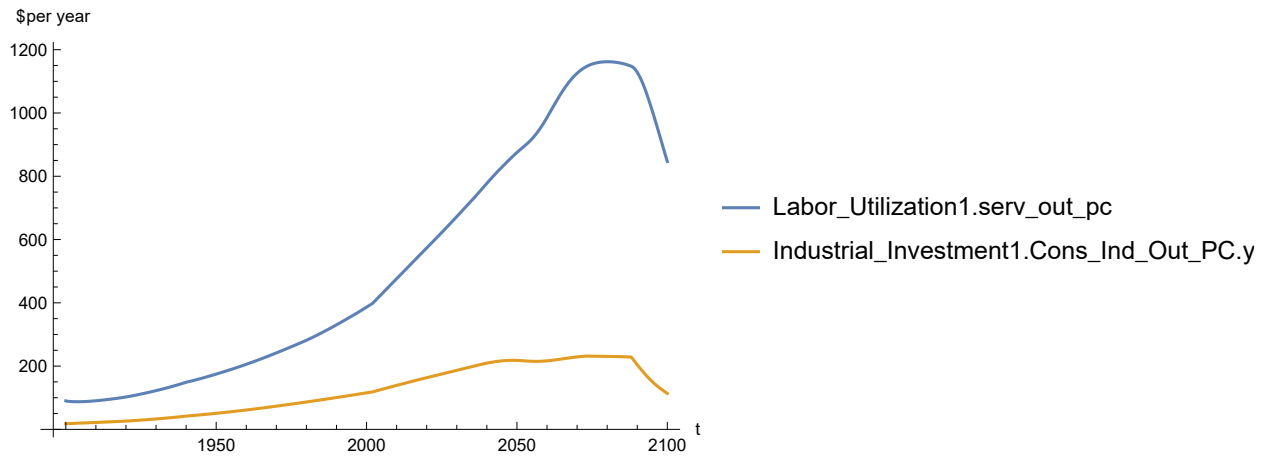


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1161.99

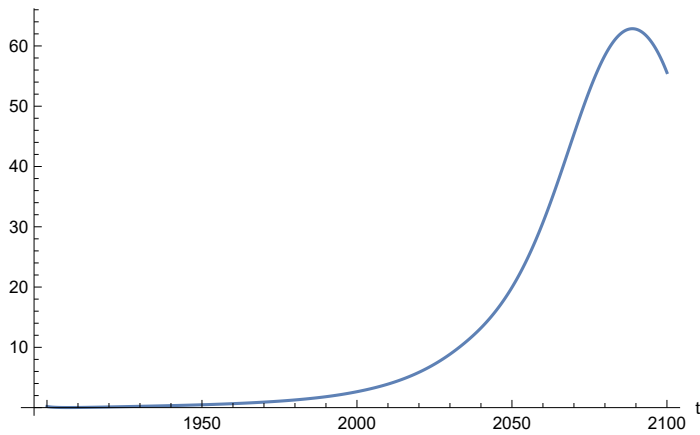
Minimum is 87.4451

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 62.8571

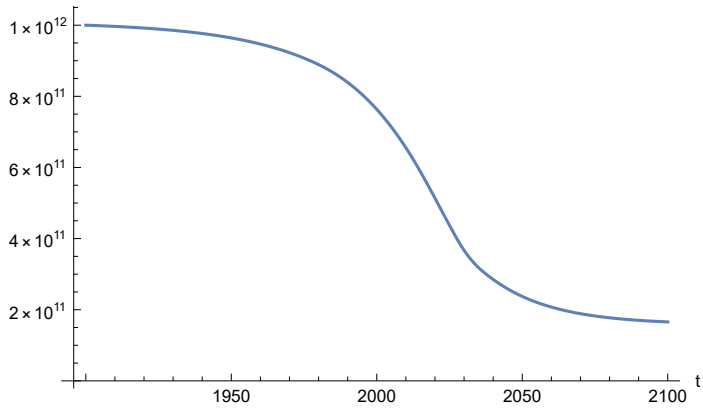
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 86. BENCHMARK SCENARIO 7, Experiment 86. $LE = LE/1.03$, $t_policy_year = 1970$.
Last modified: 30 July 2022/1200 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

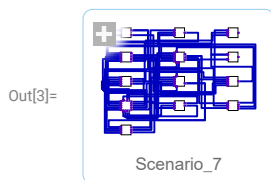
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

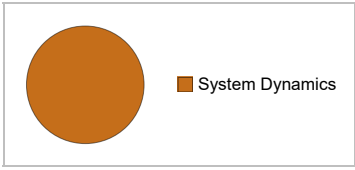
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 7.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_7"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_7
	Description	More abundant non-recoverable natural resources and birth control
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

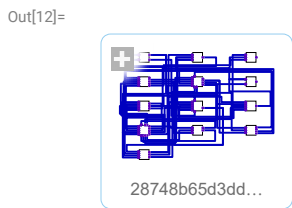
```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}} |>]
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

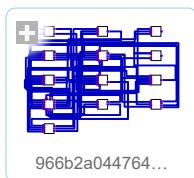
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

... **SystemModelSimulate**: At time 2076.6 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

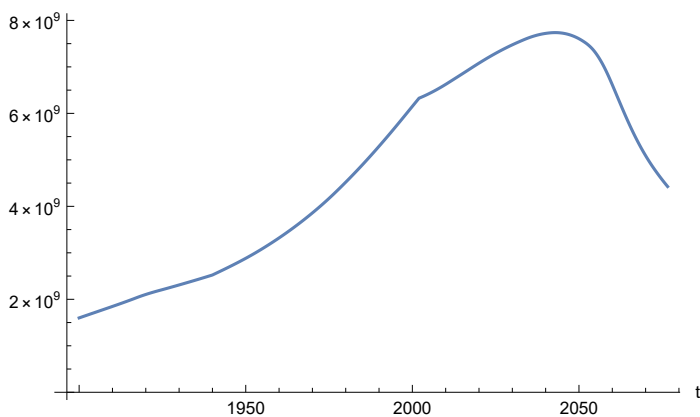
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W966b2a0447644cae886e383a3da064b8  
Time:  $1.90 \times 10^3$  to 2080. ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[22]=
```



Find max and min of population values.

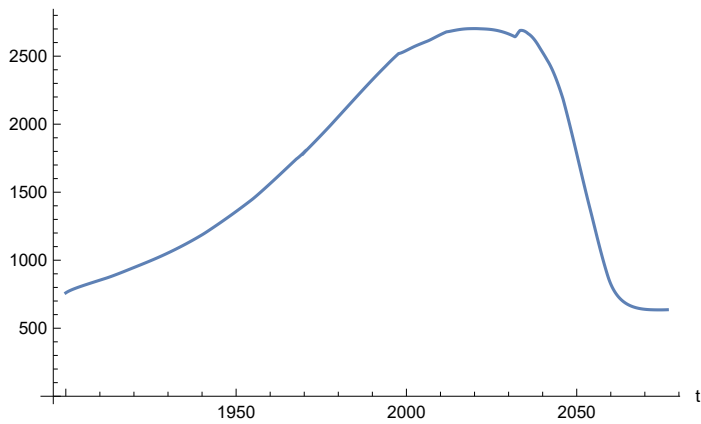
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.73743×10^9

Minimum is 1.6×10^9

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

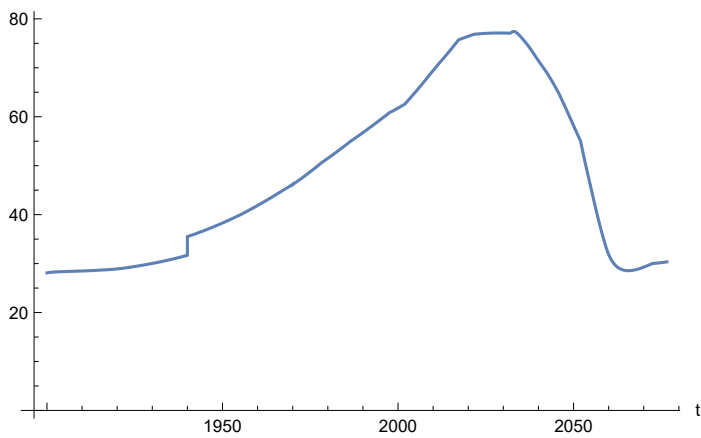
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

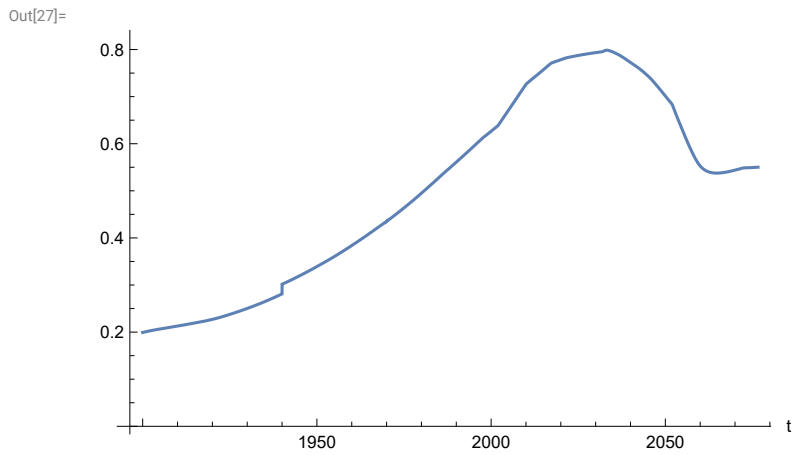
Out[25]=



In[26]:=

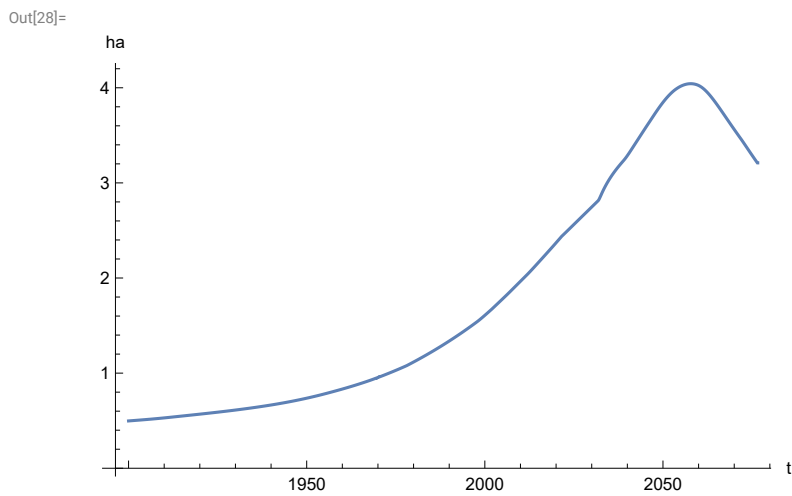
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

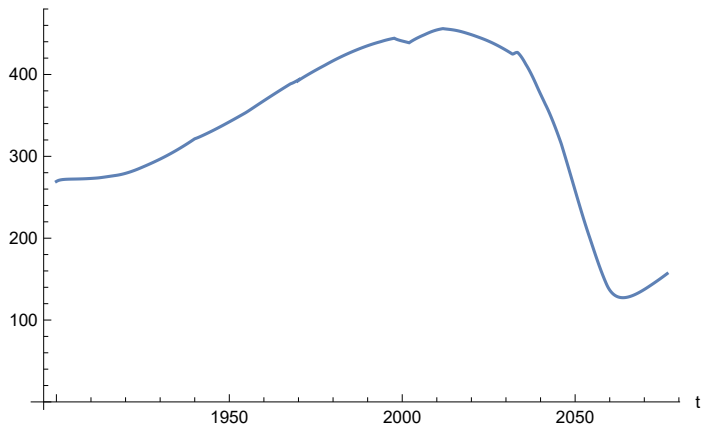
```
In[28]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

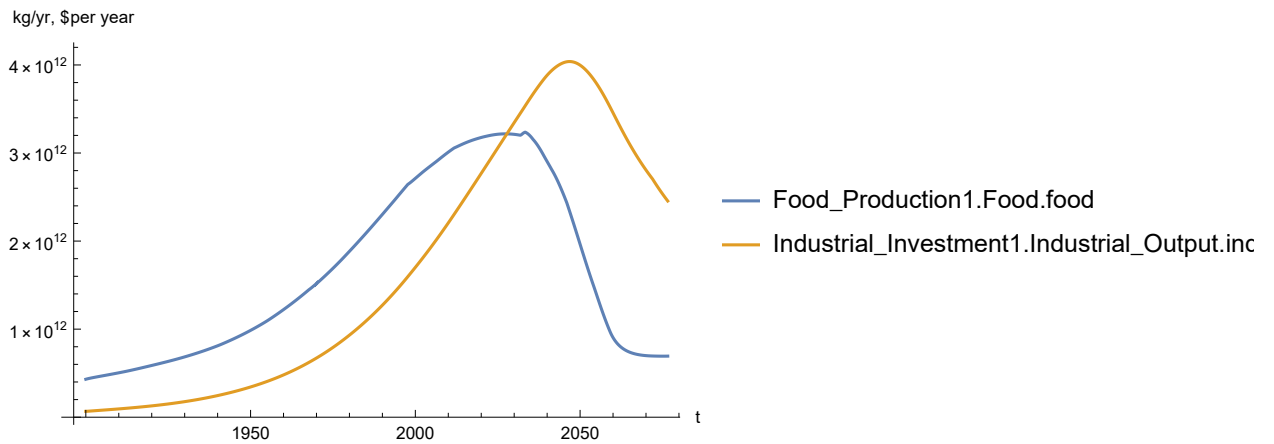
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

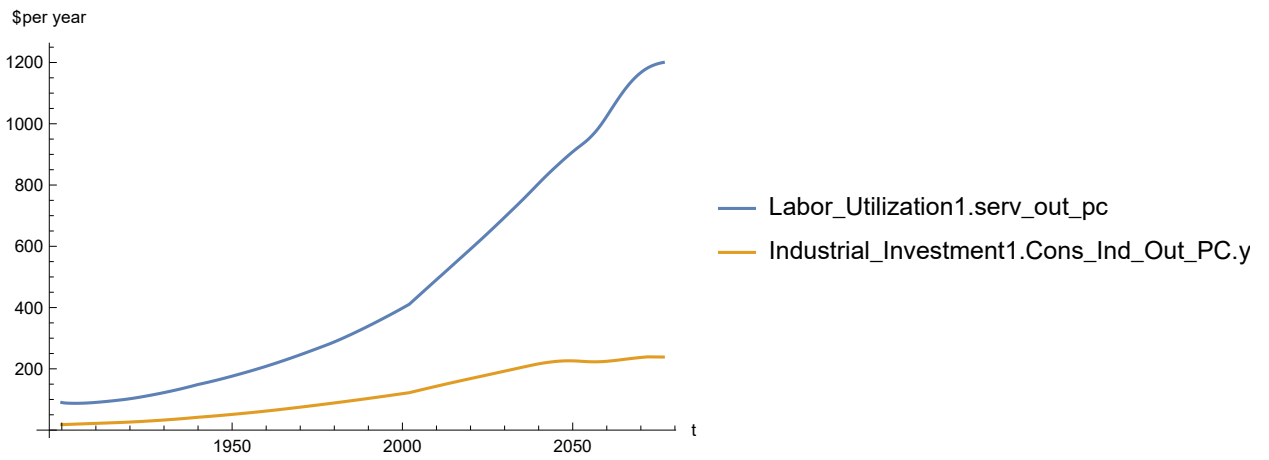
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

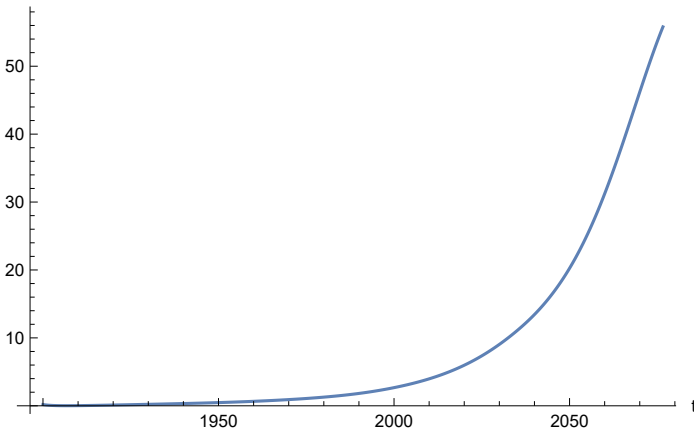
Maximum is 1200.15

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

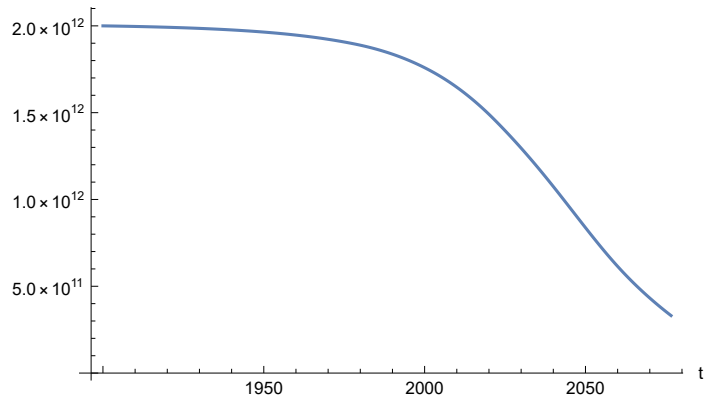
Maximum is 55.7927

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

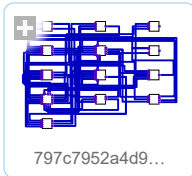


APPENDIX 87. LE/1.03, t_policy_year = 2025. Baseline Scenario 7, Experiment 87.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

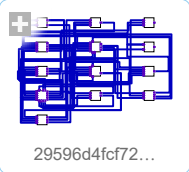
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}

Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

Out[44]=  29596d4fcf72...

Execute and plot various variables.

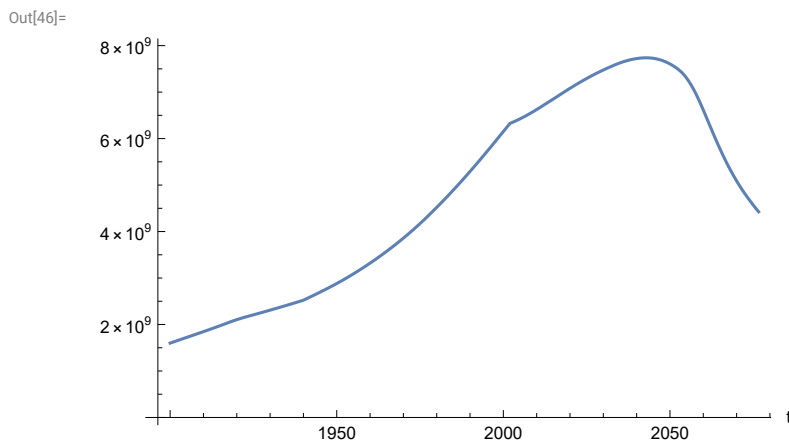
```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

 SystemModelSimulate: At time 2076.6 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

Out[45]= SystemModelSimulationData [ Model: W29596d4fcf7242d6a3d1af2229f24714
Time: 1.90 × 10³ to 2080.]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

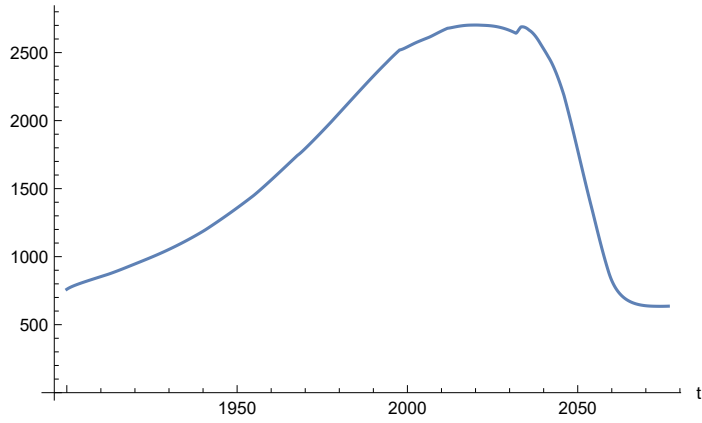
```
In[47]:= MinAndMax[basesim [{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.73793×10^9

Minimum is 1.6×10^9

In[48]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

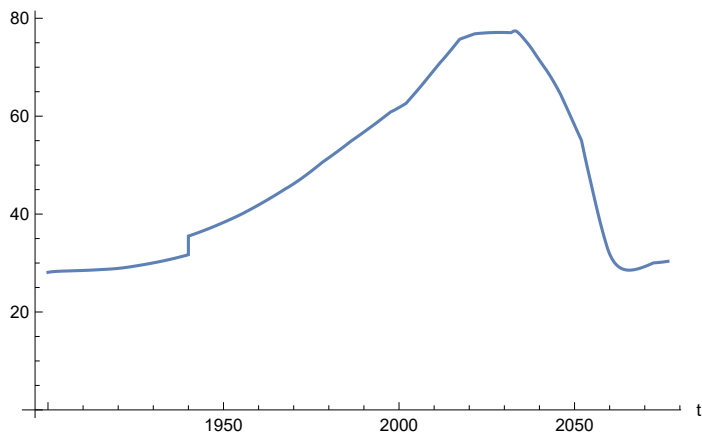
Out[48]=



Plot life expectancy, years.

In[49]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

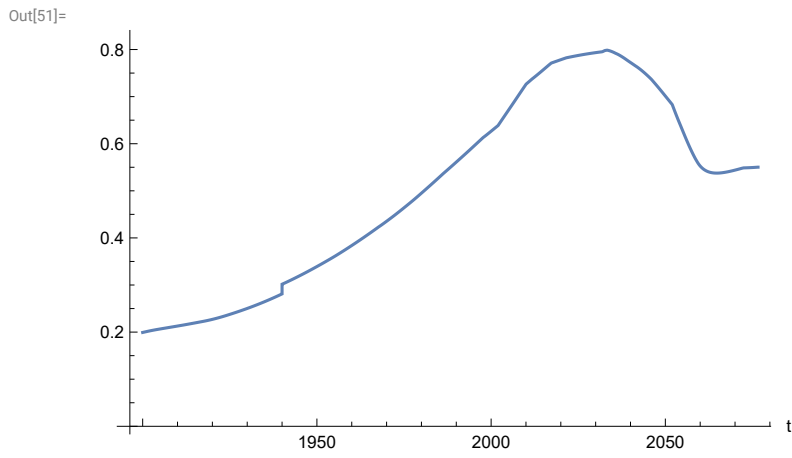
Out[49]=



In[50]:=

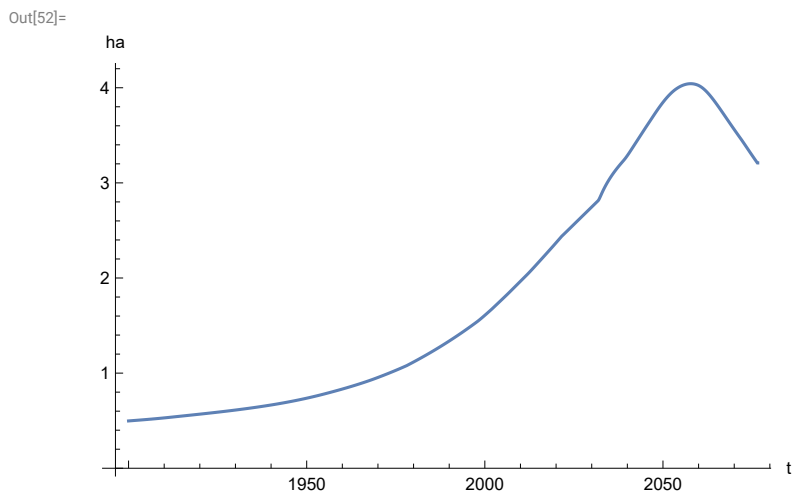
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

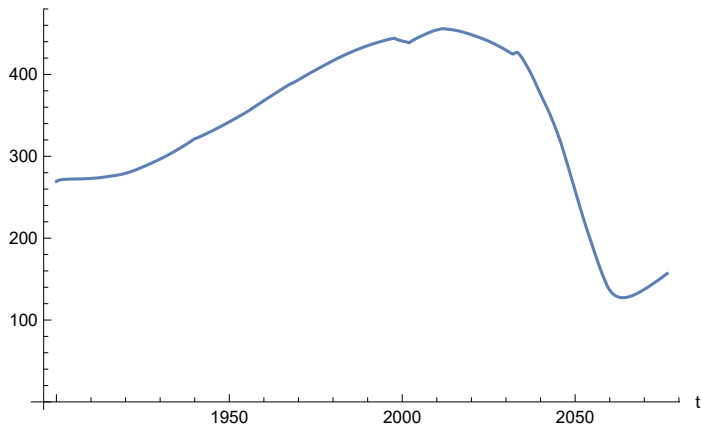
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

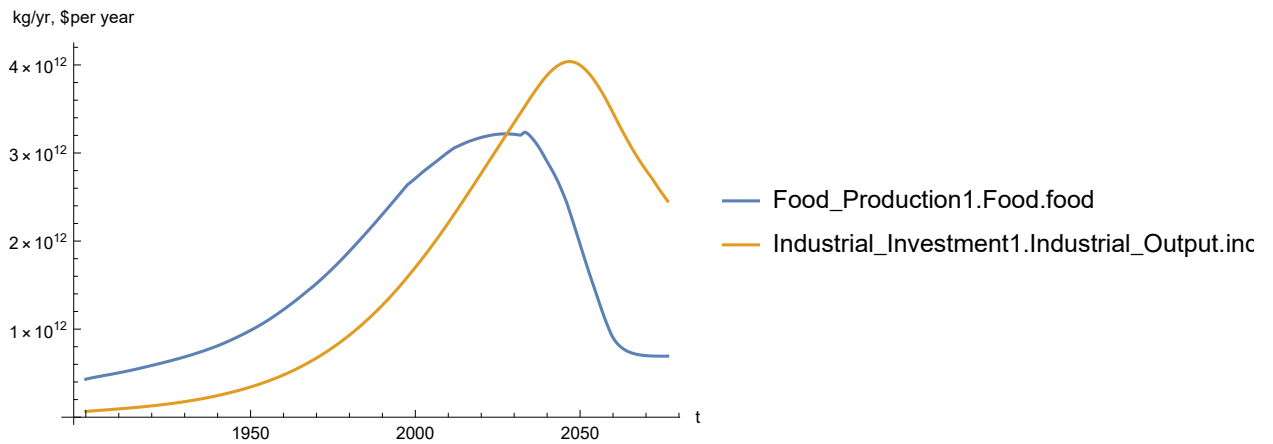
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

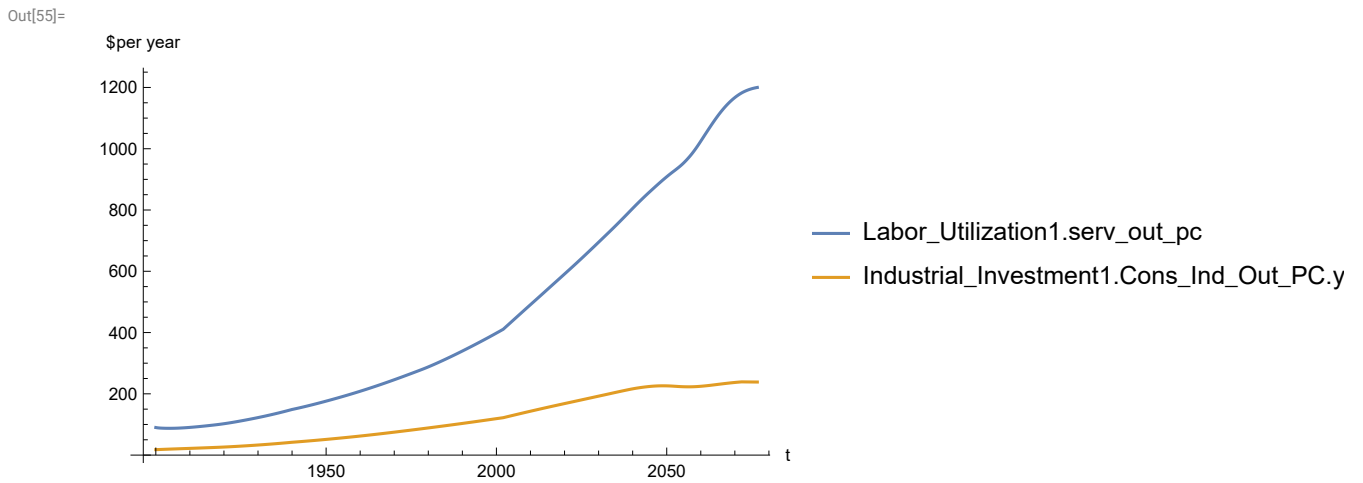
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

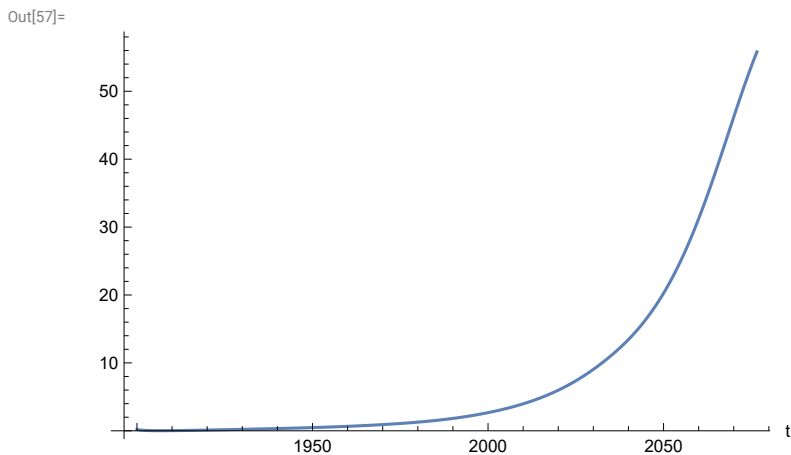
```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1200.01

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

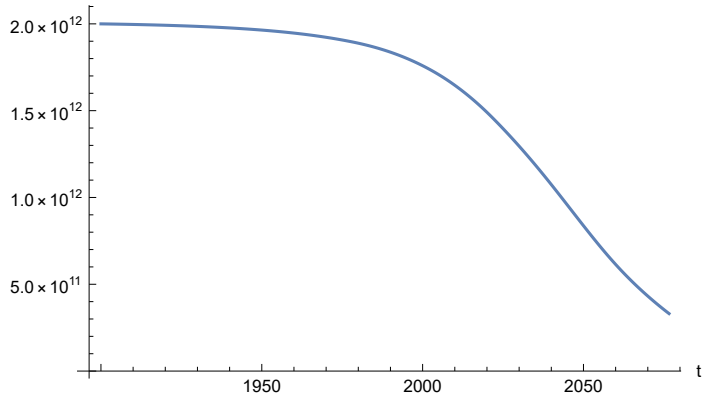
Maximum is 55.7999

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

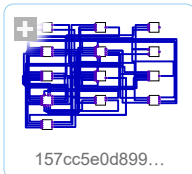


APPENDIX 88. LE/1.05, t_policy_year = 1970. Baseline Scenario 7, Experiment 88.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

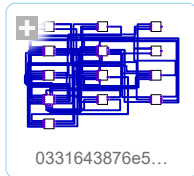
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

```
SystemModelSimulate: At time 2070.4 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range
```

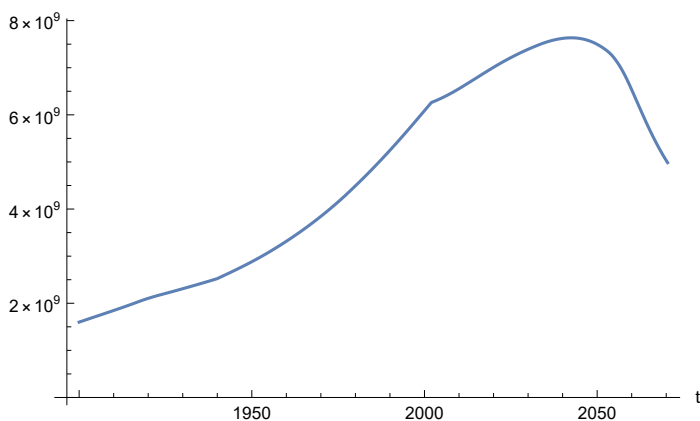
```
Out[69]=
```

```
SystemModelSimulationData [
  Model: W0331643876e54c6fa5129f7dc6012213
  Time: 1.90 × 103 to 2.07 × 103 ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

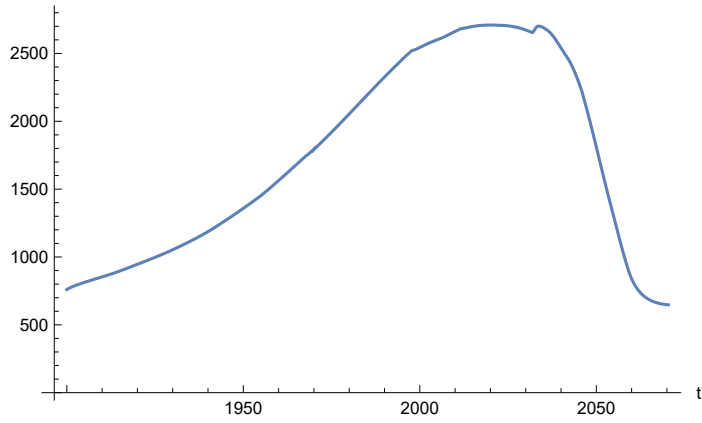
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.63508×10^9

Minimum is 1.6×10^9

```
In[72]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

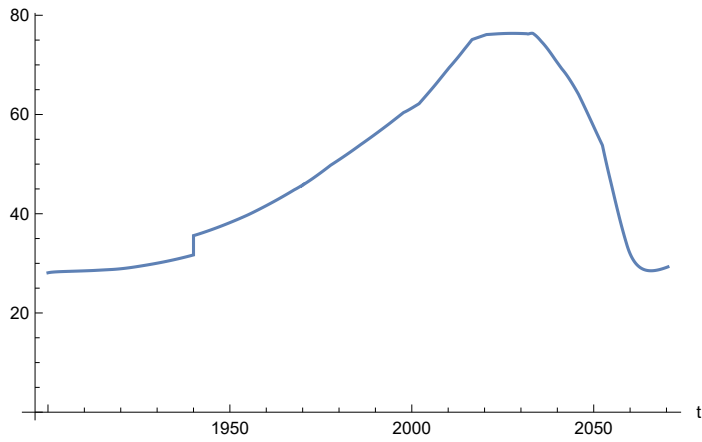
Out[72]=



Plot life expectancy, years.

```
In[73]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

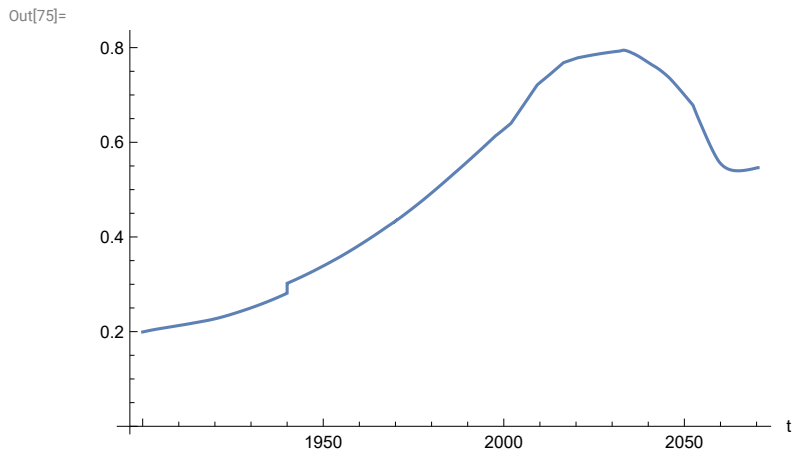
Out[73]=



In[74]=

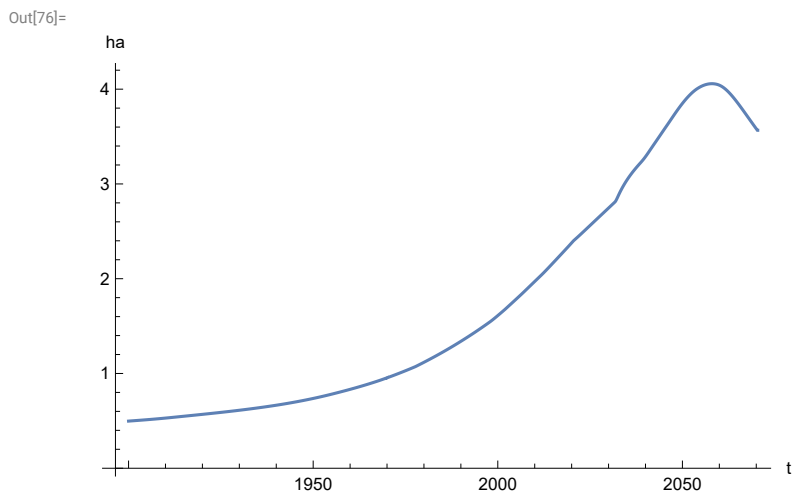
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

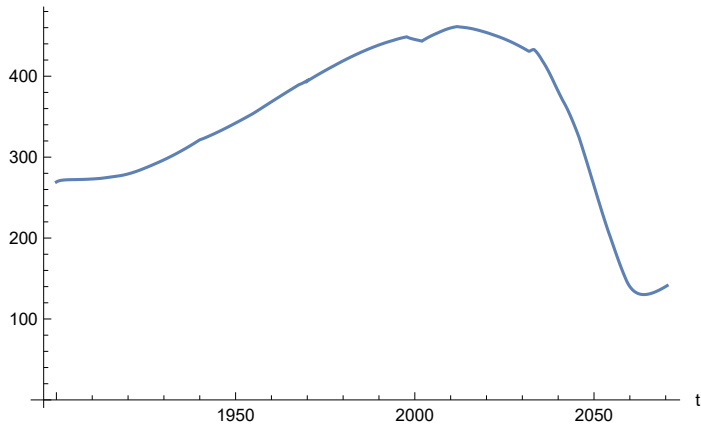
```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

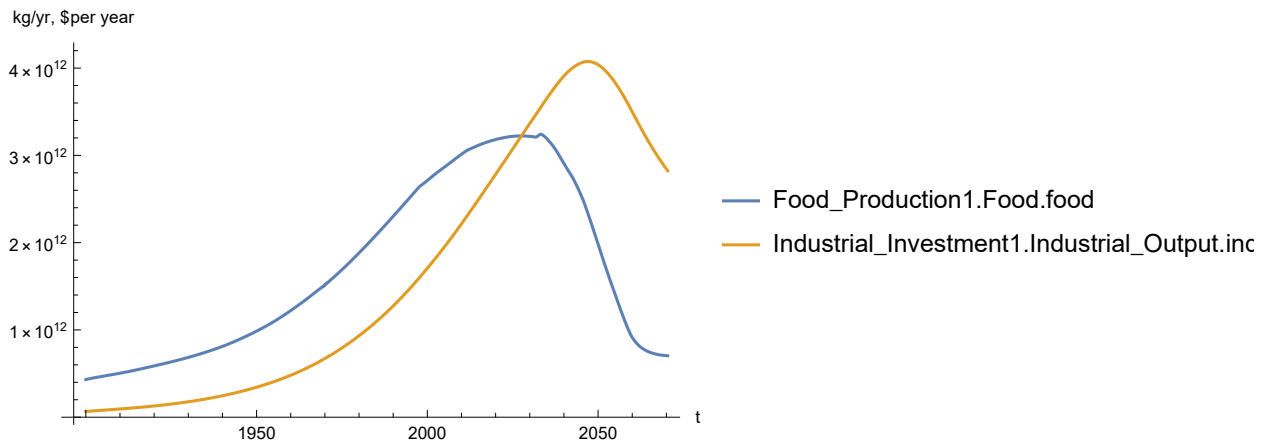
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

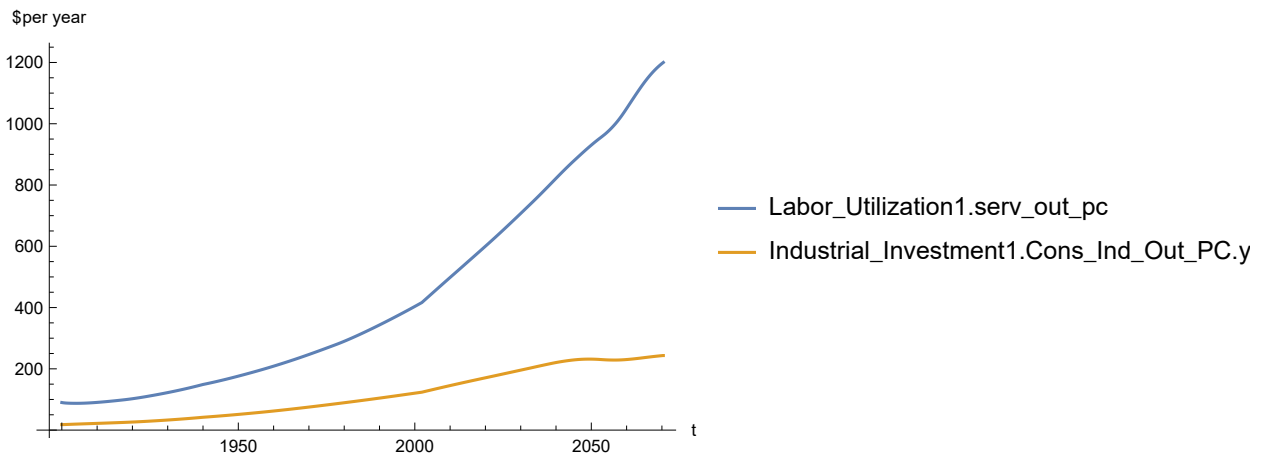
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

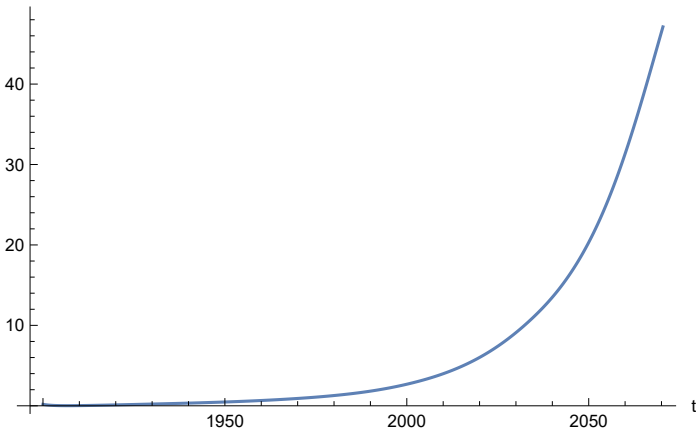
Maximum is 1200.06

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

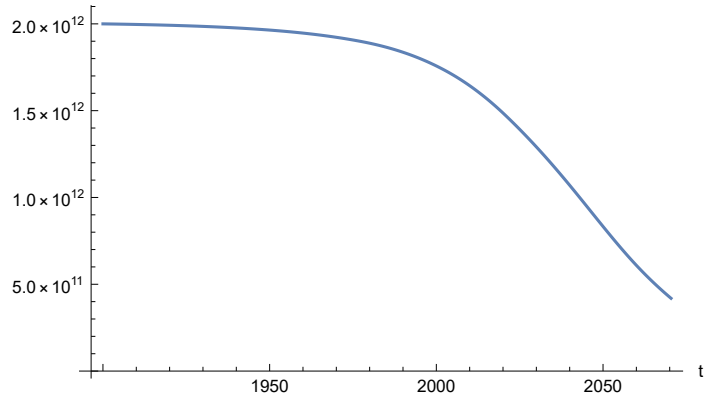
Maximum is 47.1117

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

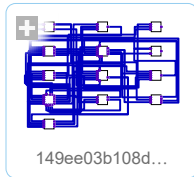
Out[83]=



APPENDIX 89. Baseline Scenario 7, Experiment 89. LE = LE/1.05, t_policy_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

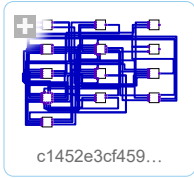
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```


Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



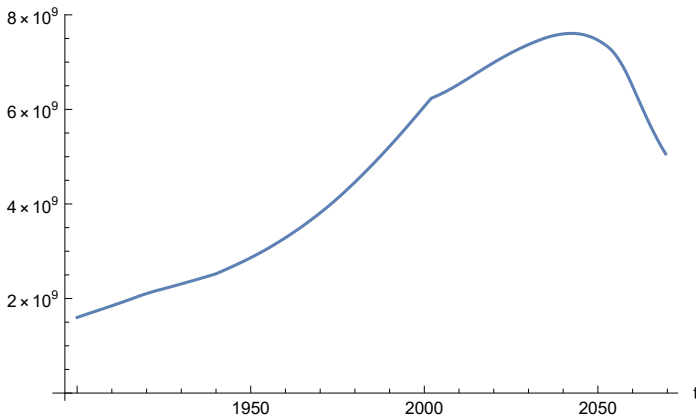
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
SystemModelSimulate: At time 2069.5 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range
Out[93]=
```

SystemModelSimulationData [ Model: Wc1452e3cf459483a9da3fda8d2a90db4
Time: 1.90×10^3 to 2070.]

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

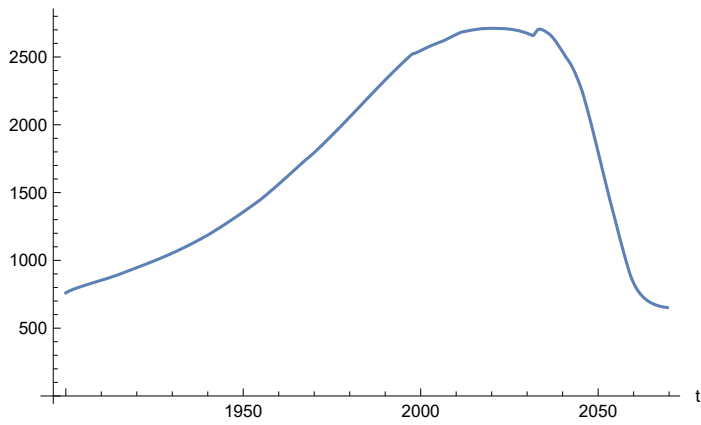


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.60732 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

In[96]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

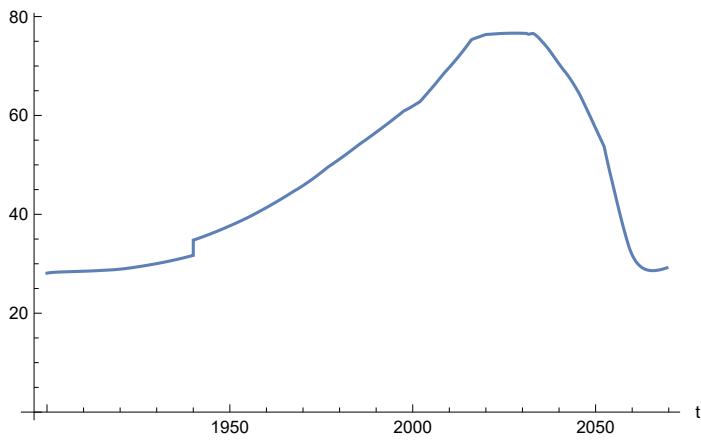
Out[96]=



Plot life expectancy, years.

In[97]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

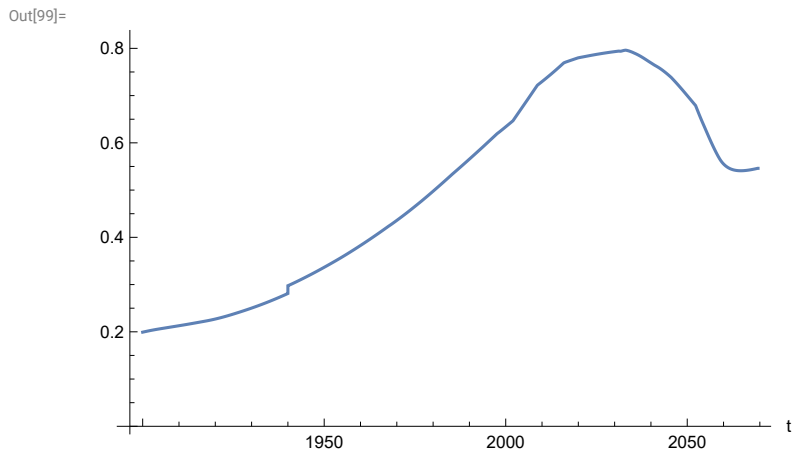
Out[97]=



In[98]=

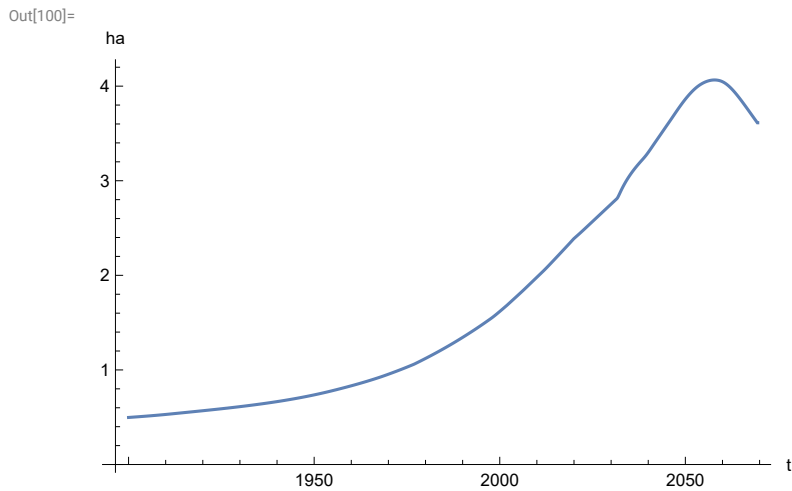
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

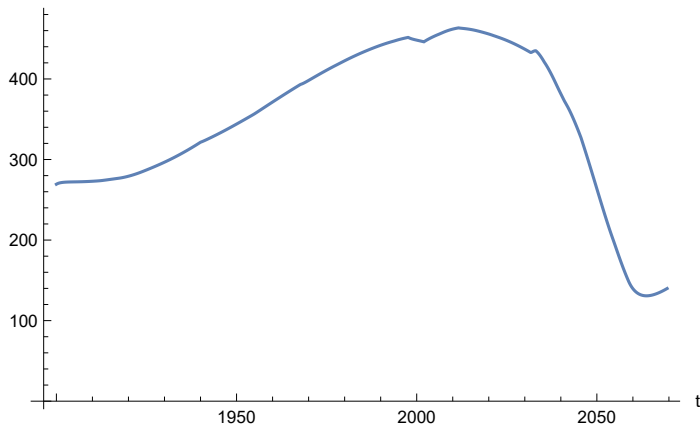


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

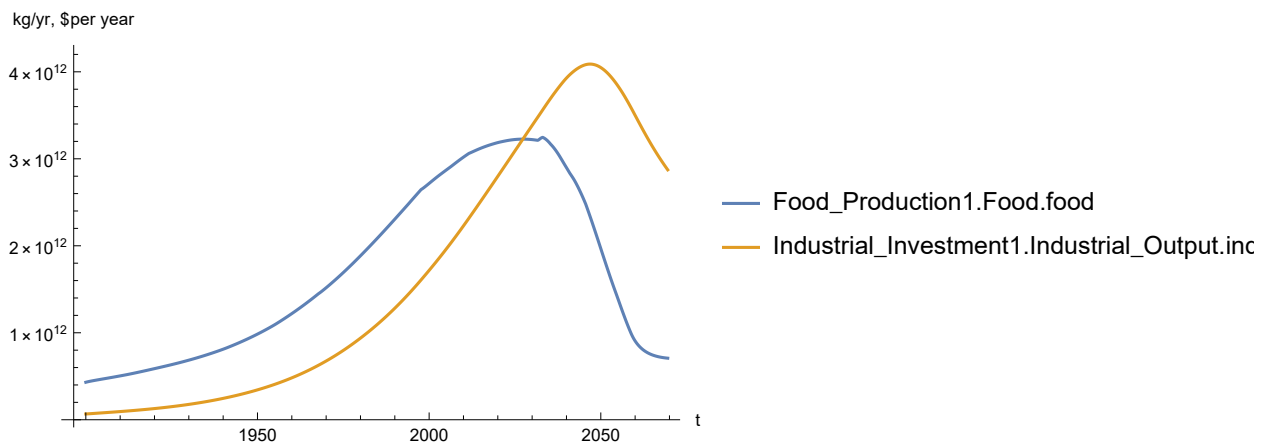


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

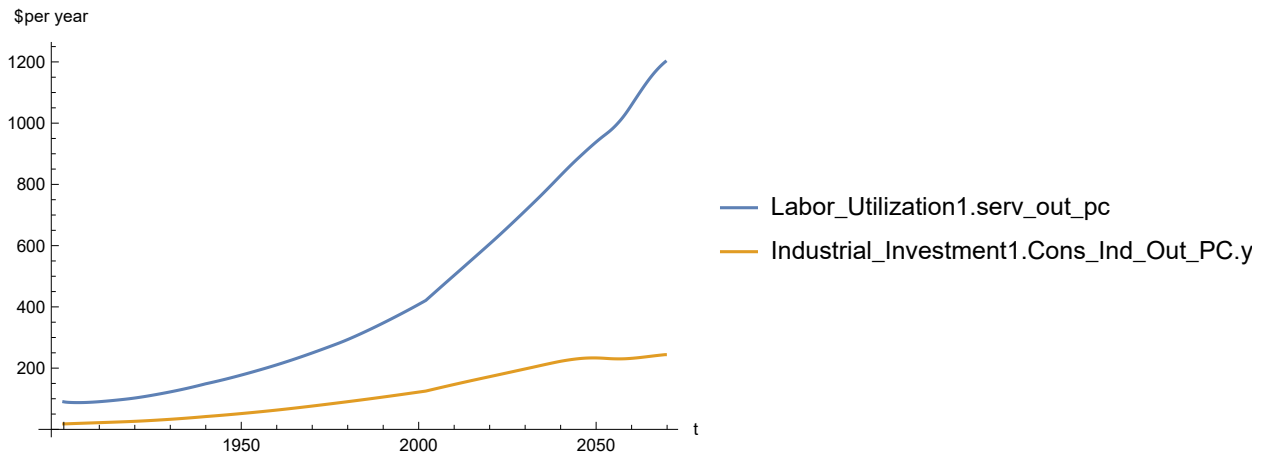


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1200.57

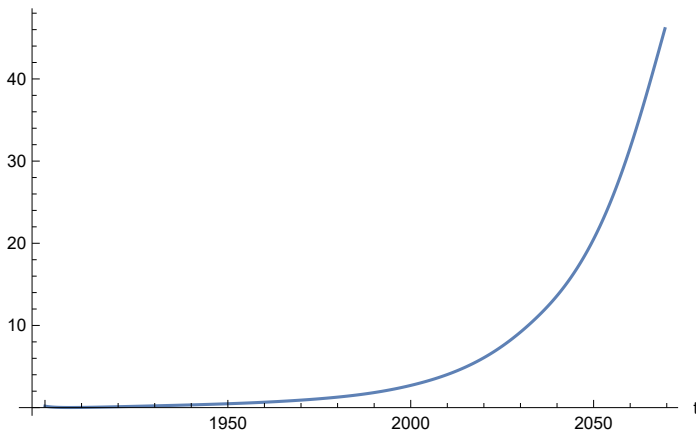
Minimum is 87.4451

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 46.1126

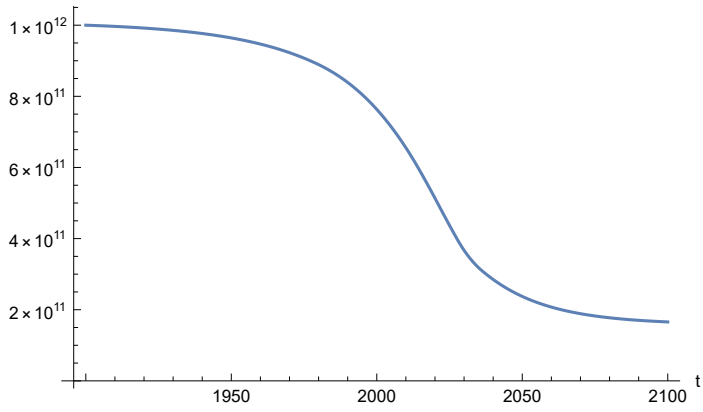
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[107]=



**APPENDIX 90. BENCHMARK SCENARIO 7, Experiment 90. LE = LE/1.1, t_policy_year = 1970.
Last modified: 30 July 2022/1330 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

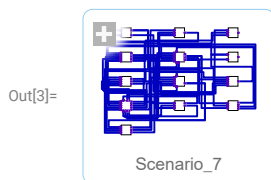
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

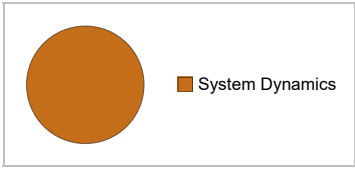
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 7.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_7"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_7
	Description	More abundant non-recoverable natural resources and birth control
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

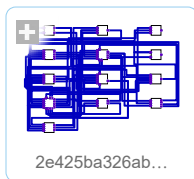
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}

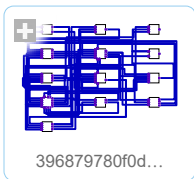
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}

Set t_policy_year to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

Out[20]=




Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

SystemModelSimulate: At time 2062.9 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

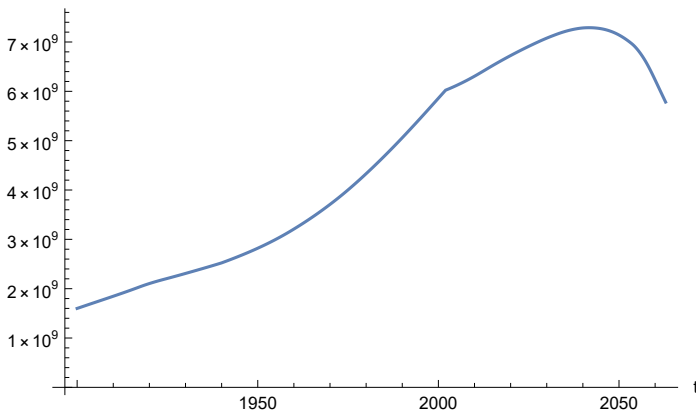
Out[21]=

SystemModelSimulationData [ Model: W396879780f0d444abc0b3d288c982bed
Time: 1.90×10^3 to 2.06×10^3]

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

Out[22]=



Find max and min of population values.

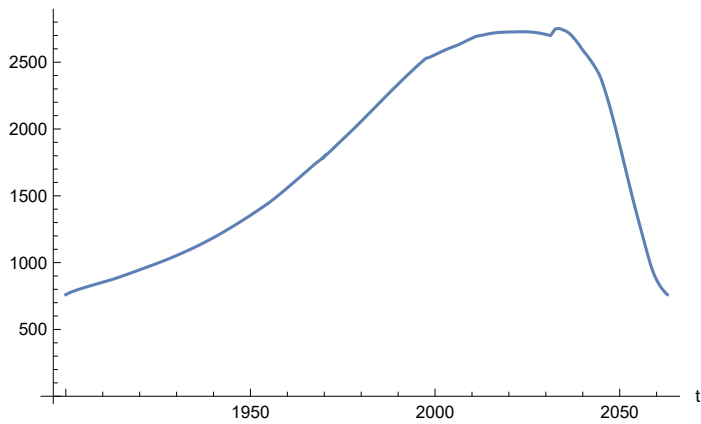
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.29002×10^9

Minimum is 1.6×10^9

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

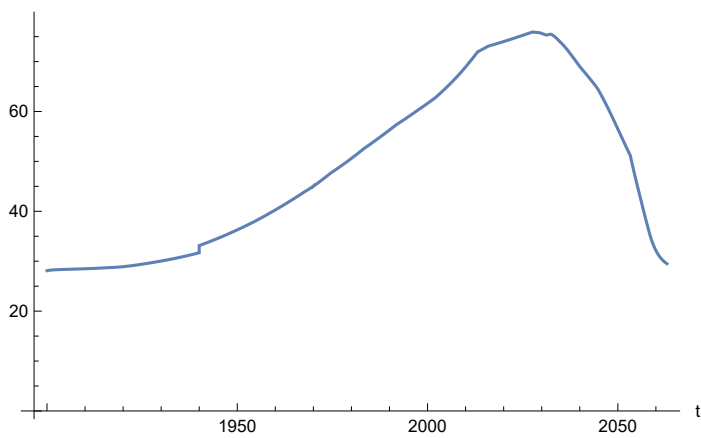
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[25]=

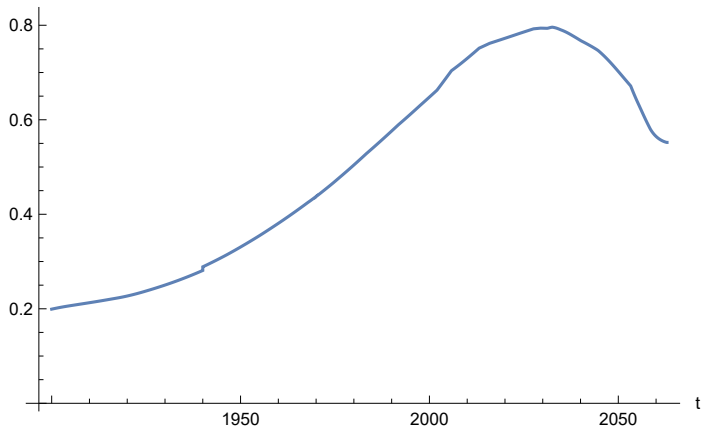


In[26]:=

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

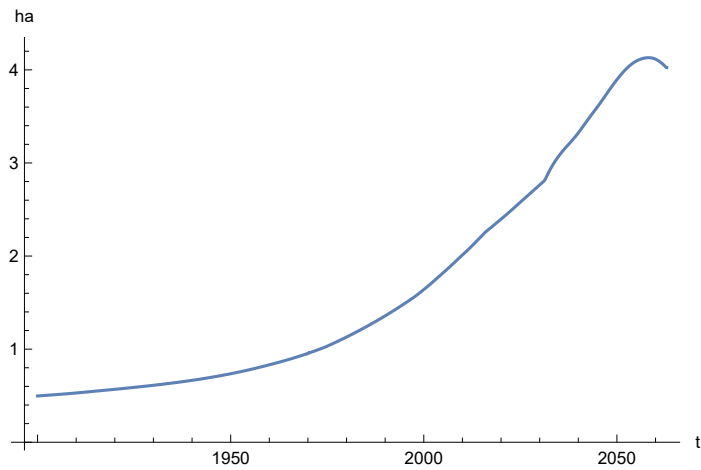
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

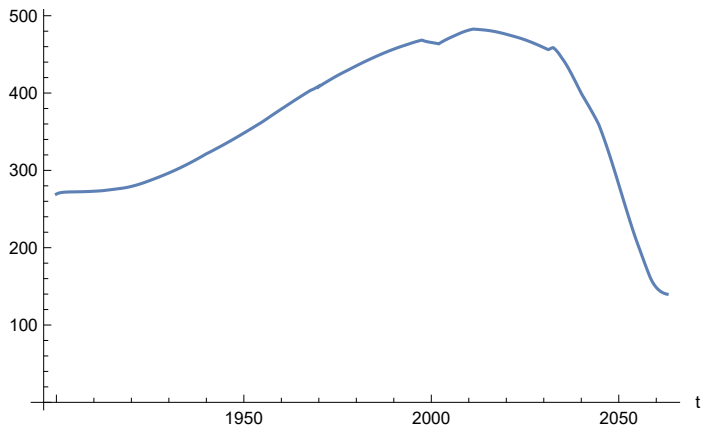
Out[28]=



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

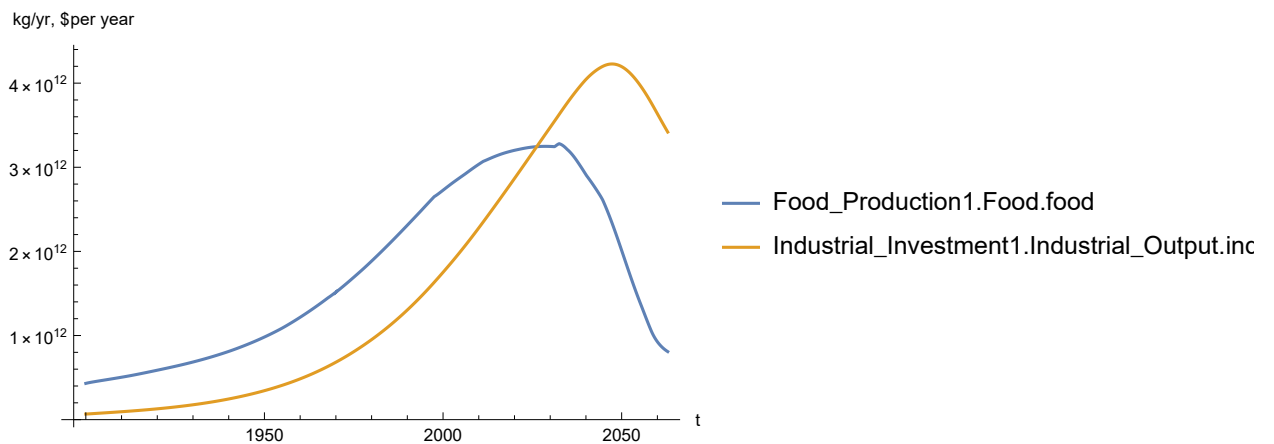
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

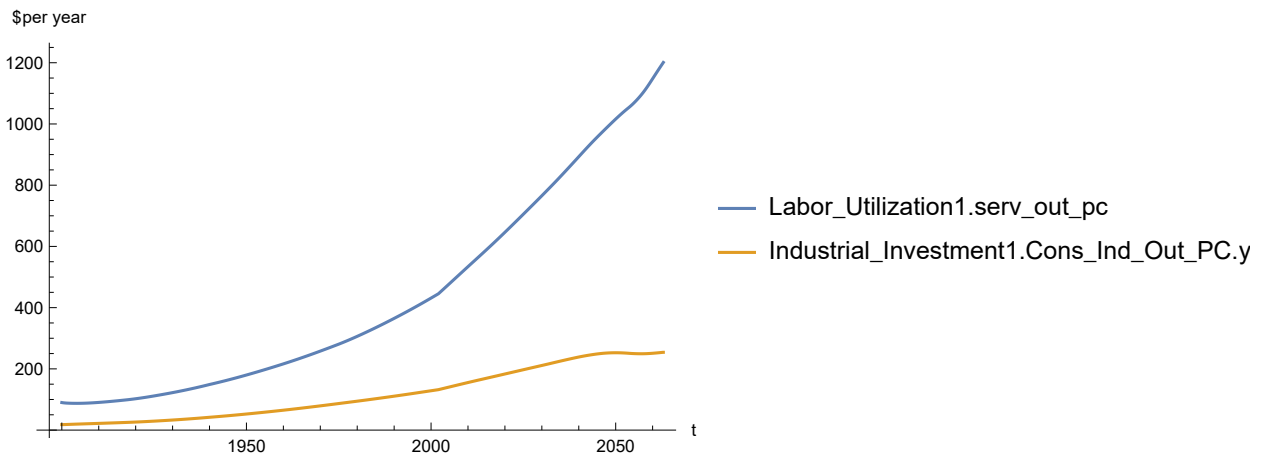
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

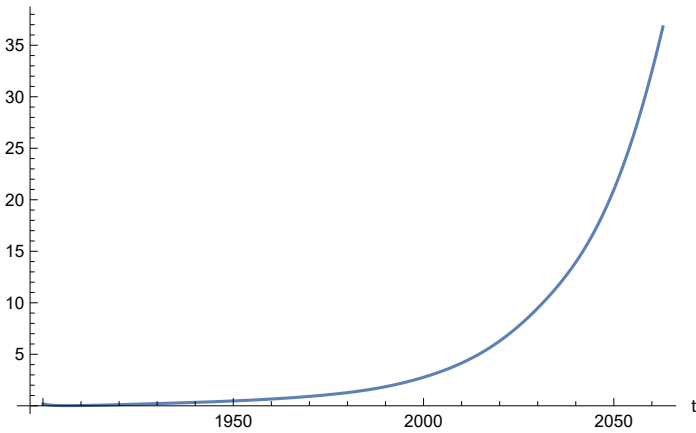
Maximum is 1200.91

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

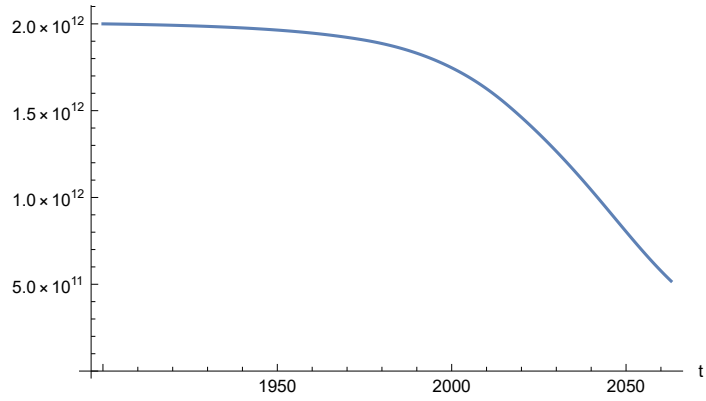
Maximum is 36.7835

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

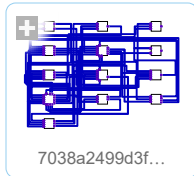


APPENDIX 91. LE/1.1, t_policy_year = 2025. Baseline Scenario 7, Experiment 91.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

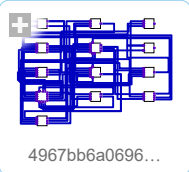
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}


Set t_policy_year to 2025.



```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

Out[44]=  4967bb6a0696...

Execute and plot various variables.

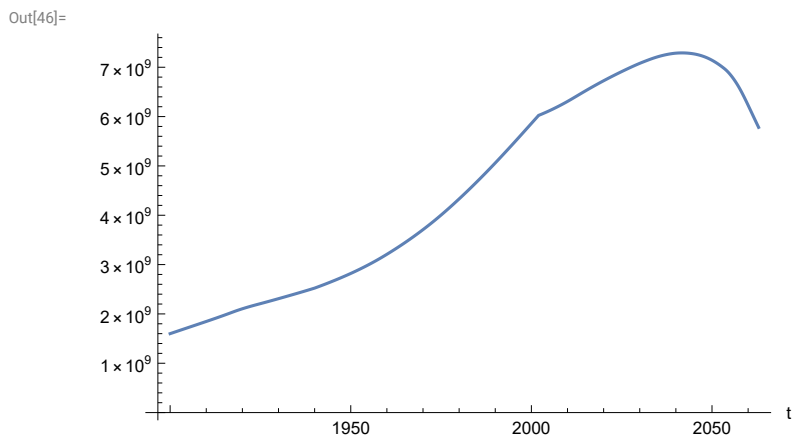
```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

 SystemModelSimulate: At time 2062.9 s: In SystemDynamics.Functions.Utilities.Piecewise: Out of range

Out[45]= SystemModelSimulationData [  Model: W4967bb6a06964f2683be9ab4d6d884c4
Time: 1.90×10^3 to 2.06×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

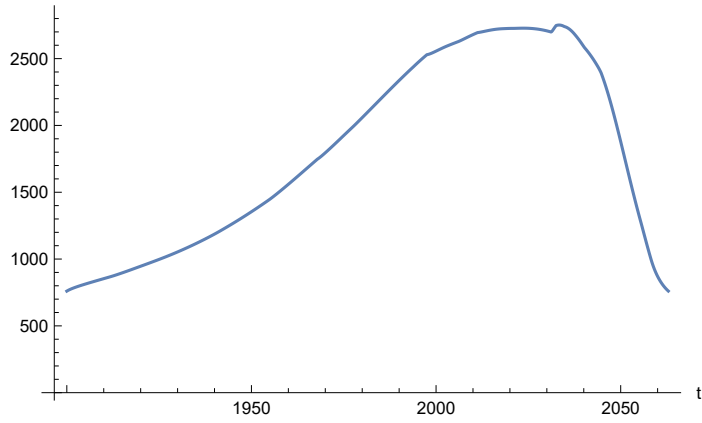
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.2906×10^9

Minimum is 1.6×10^9

In[48]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

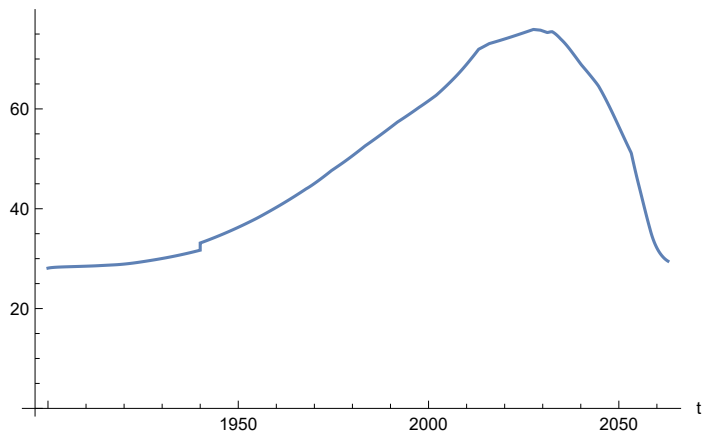
Out[48]=



Plot life expectancy, years.

In[49]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

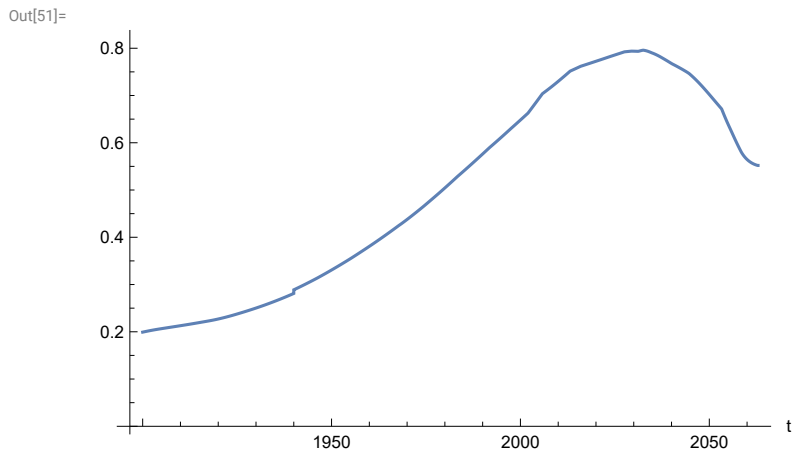
Out[49]=



In[50]=

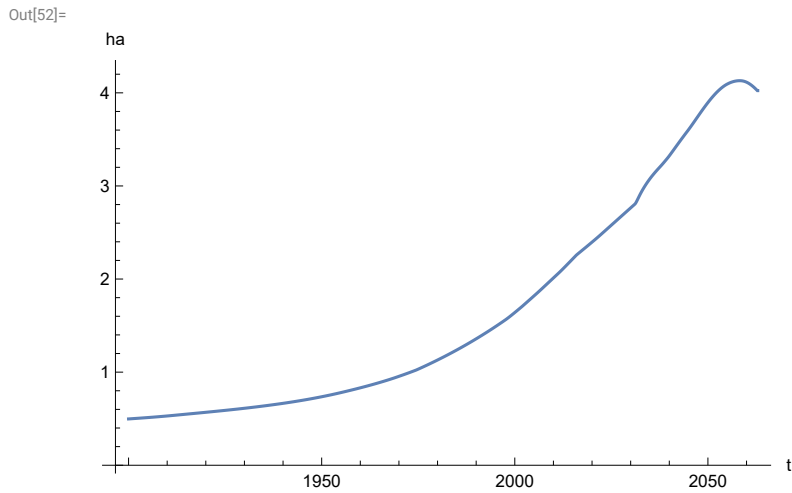
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

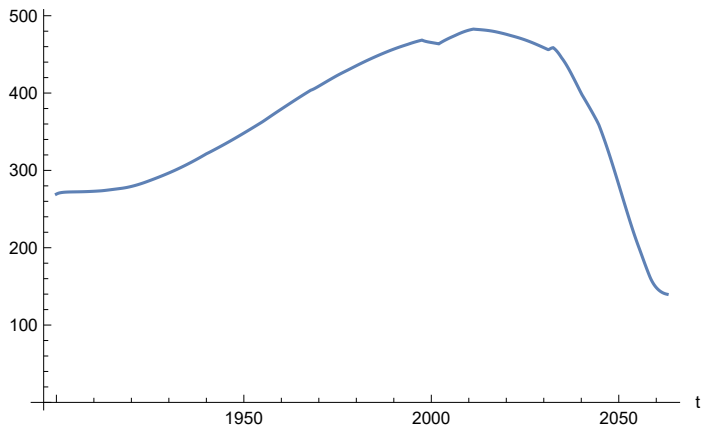
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

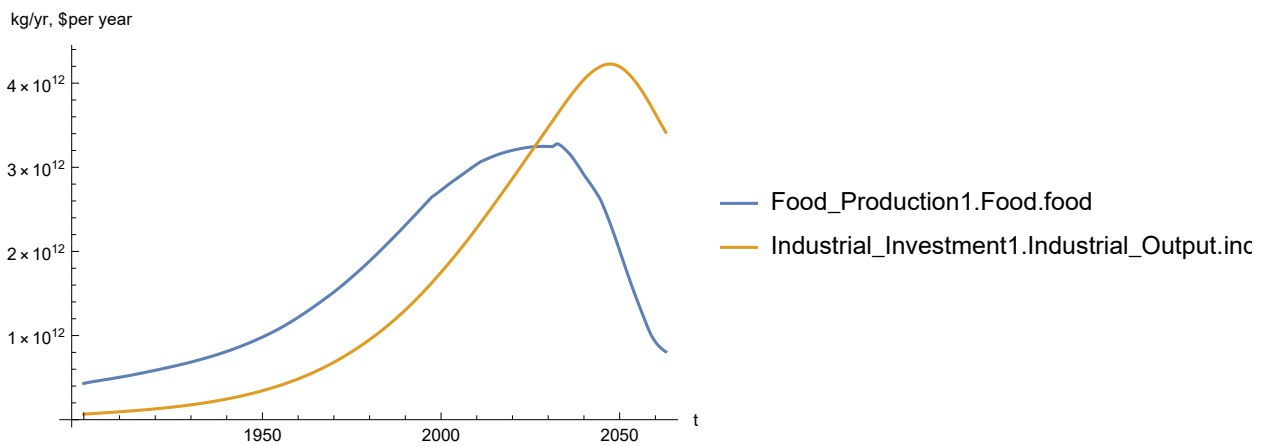
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

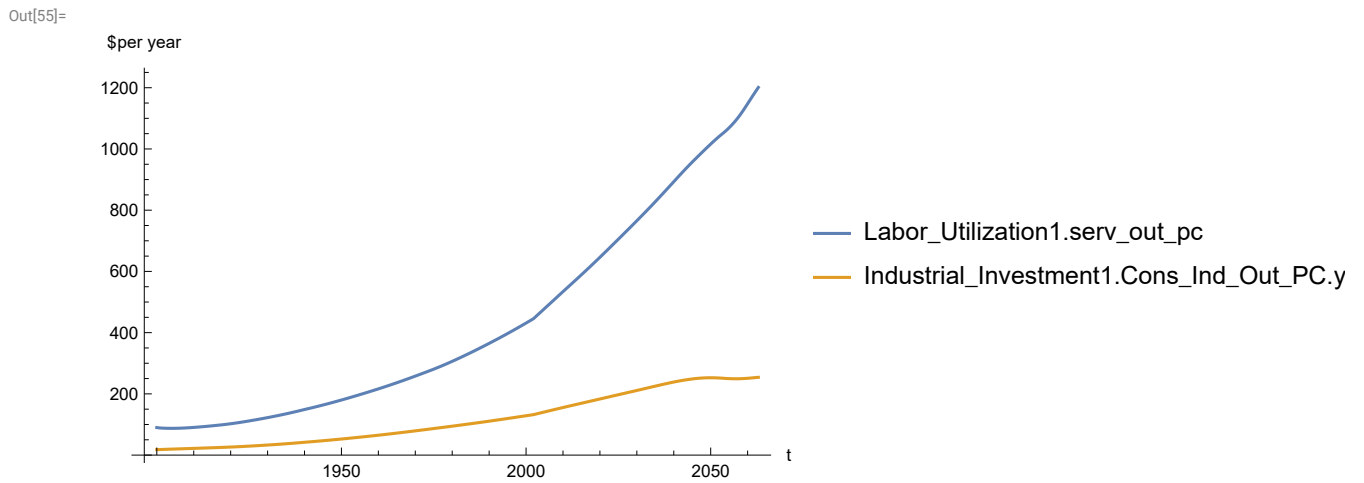
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

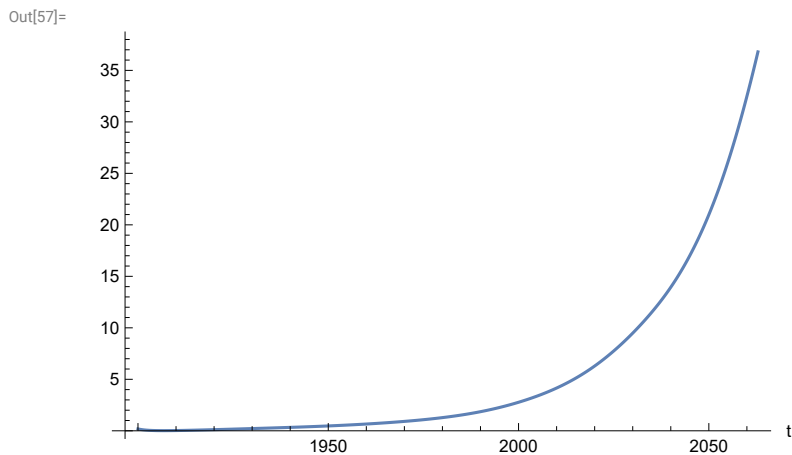
```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 1200.9

Minimum is 87.4451

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

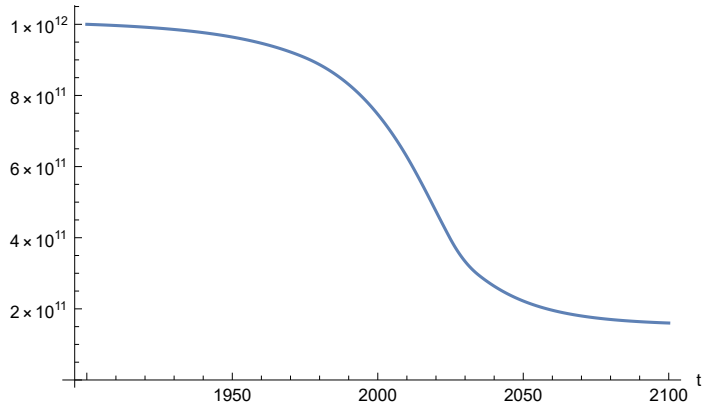
Maximum is 36.7967

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=



APPENDIX 92. BENCHMARK SCENARIO 8, Experiment 92. `t_policy_year = 2002.`

Last modified: 30 July 2022/1500 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

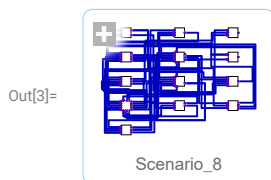
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

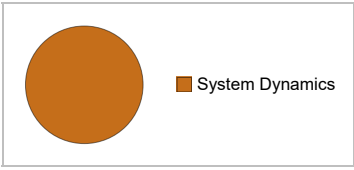
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 8.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_8"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_8
	D	More abundant non-recoverable natural resources, birth control, and stable industrial output
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show the default value of `t_policy_year`.

In[5]:= **SystemModel[mysim][{"ParameterValues", "t_policy_year"}]**

Out[5]= {t_policy_year → 2002}

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

In[6]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[7]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[8]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[9]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute Benchmark Scenario 1 and plot various variables

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

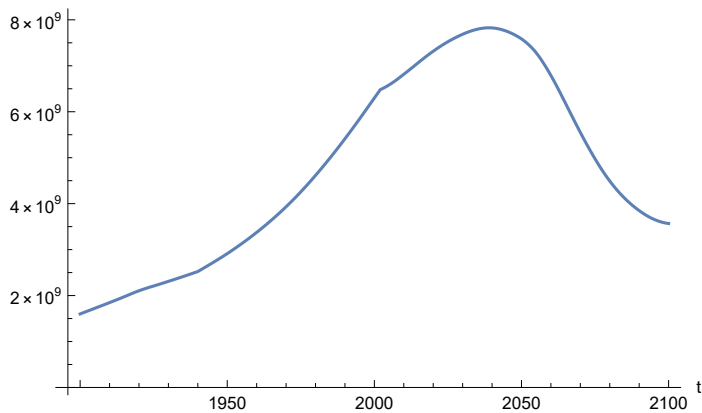
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Scenario_8
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

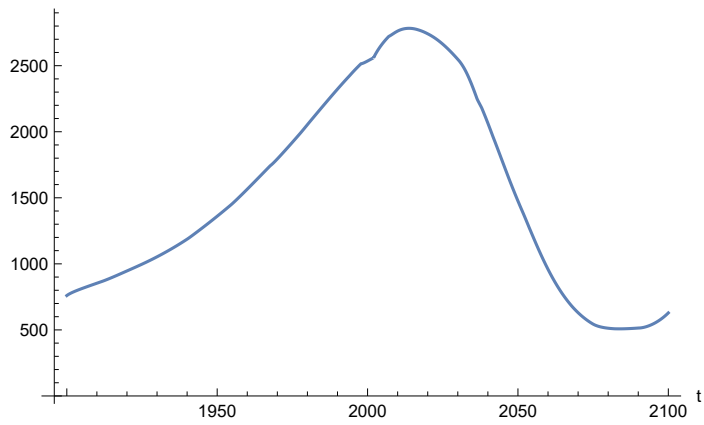
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.82639 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

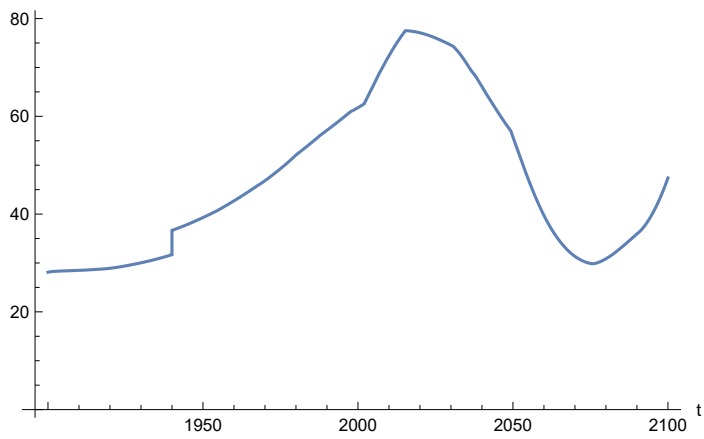
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

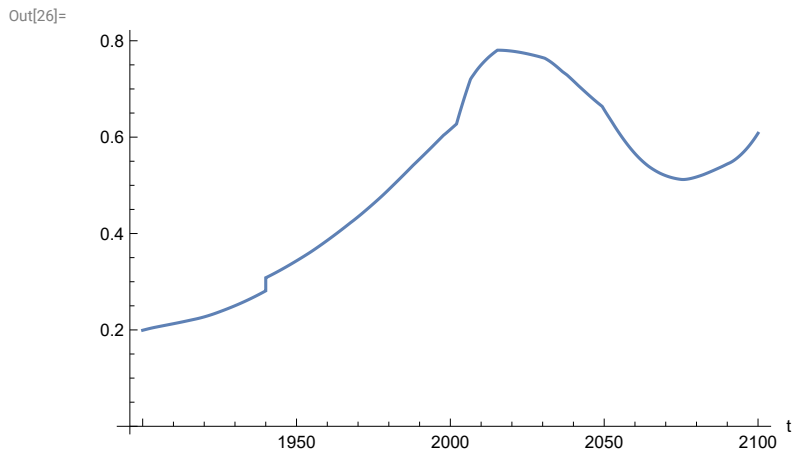
Out[24]=



In[25]:=

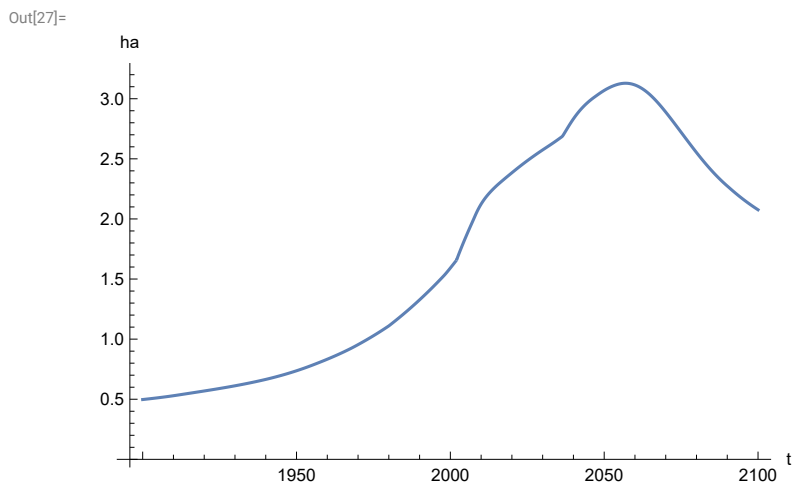
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

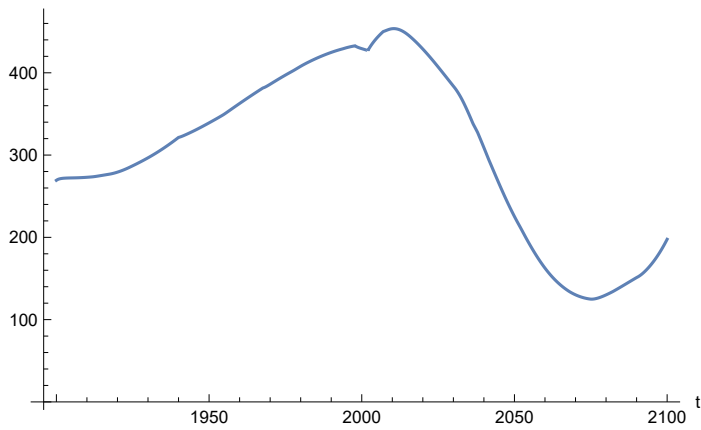
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

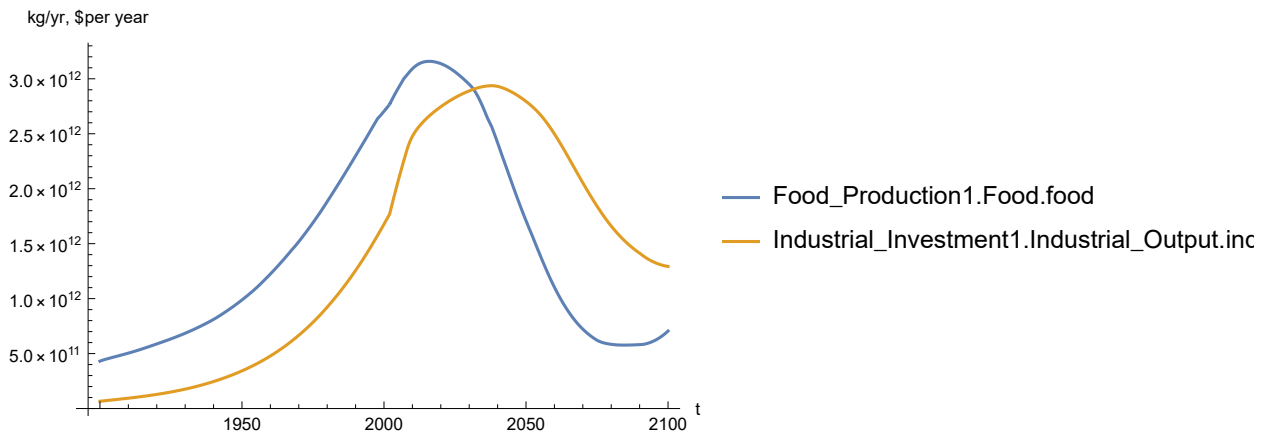
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

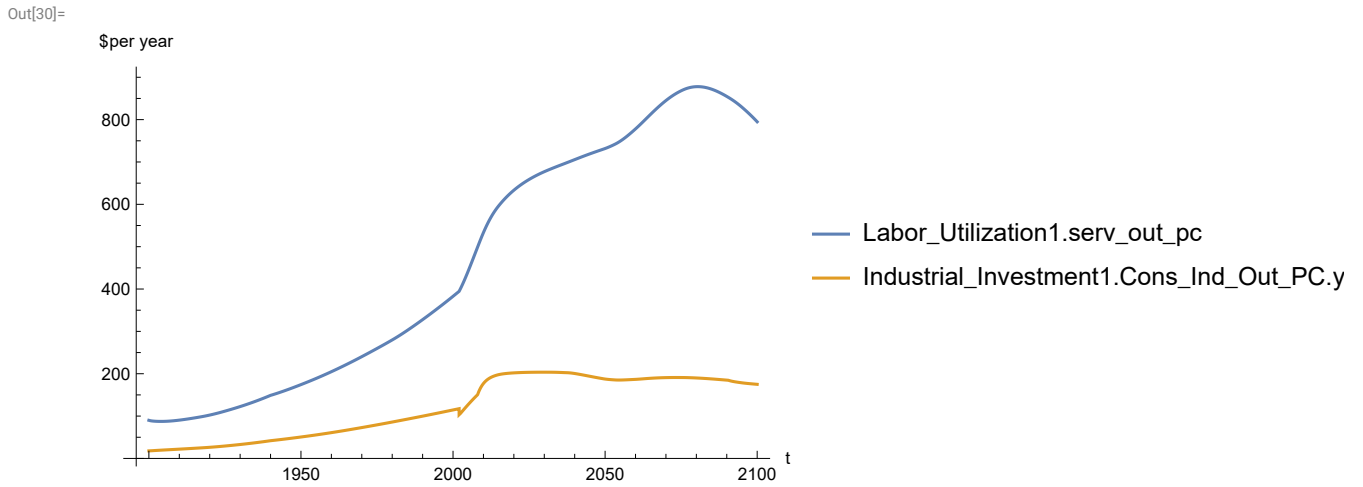
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

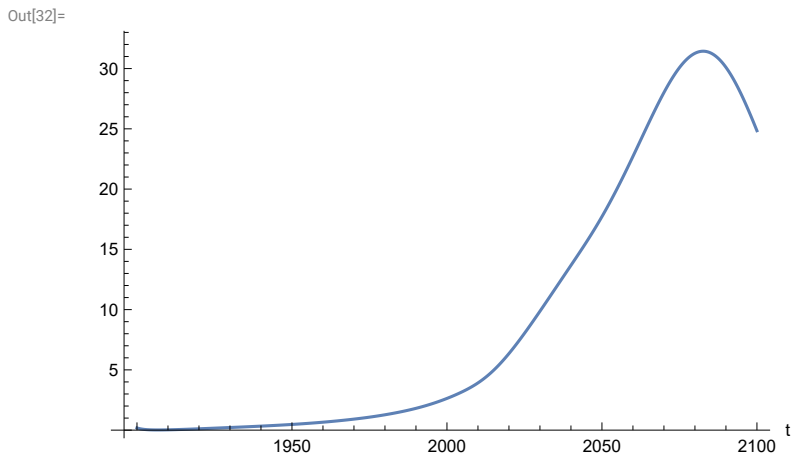


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 877.873
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



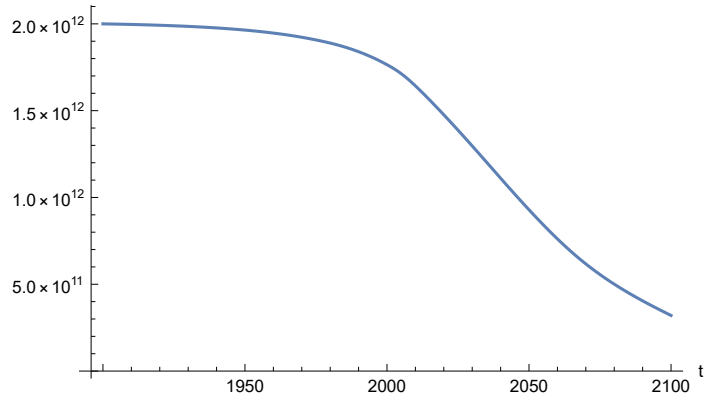
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 31.4397
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

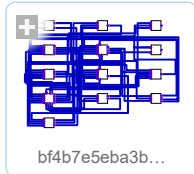


APPENDIX 93. $t_policy_year = 1970$, Benchmark Scenario 8, Experiment 93

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.


```
In[35]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[35]=
```



```
In[36]:= testsim1970 = SystemModelSimulate[newmysim1970]
```

```
Out[36]=
```

```
SystemModelSimulationData [  Model: Wbf4b7e5eba3b4441886f57b0e41282b2  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of t_policy_year .

```
In[37]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
```

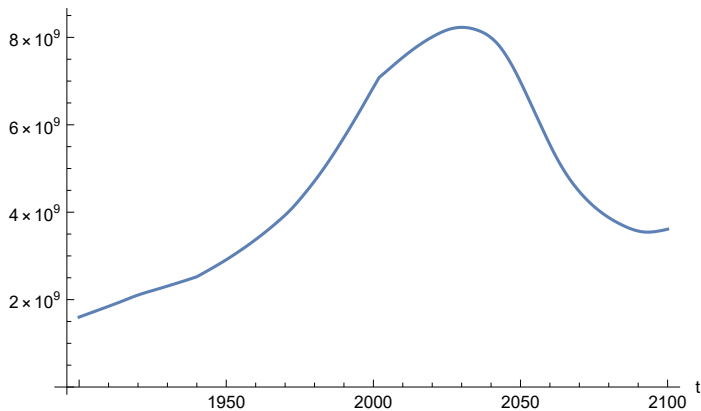
```
Out[37]=
```

```
{t_policy_year → 1970}
```

Plot the world population, people.

```
In[38]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
```

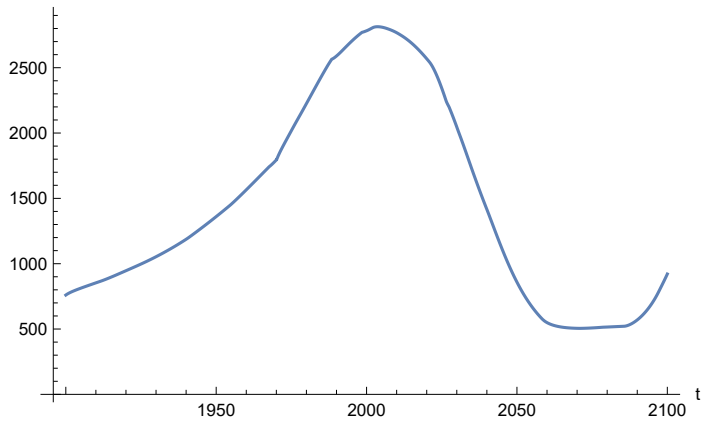
```
Out[38]=
```



Find max and min of y values.

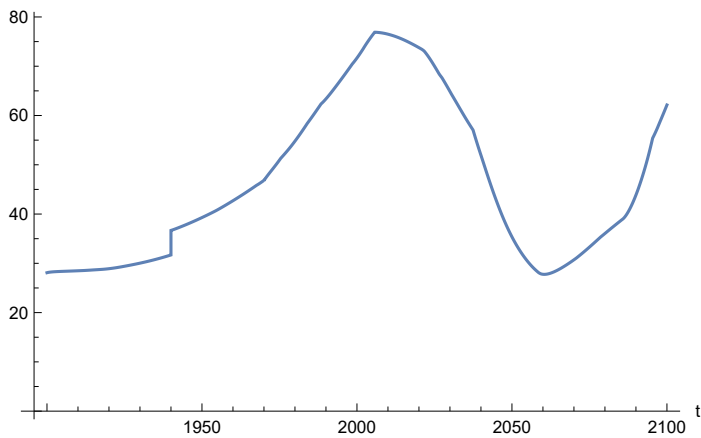
```
In[39]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.22943 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[40]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
Out[40]=
```



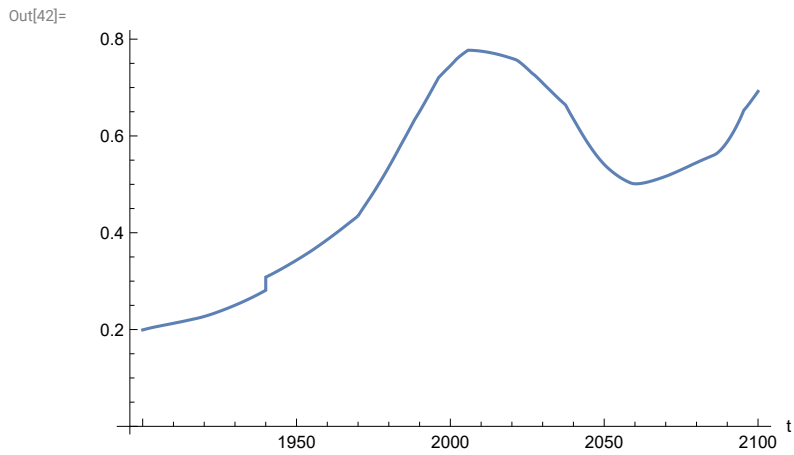
Plot life expectancy, in years.

```
In[41]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[41]=
```



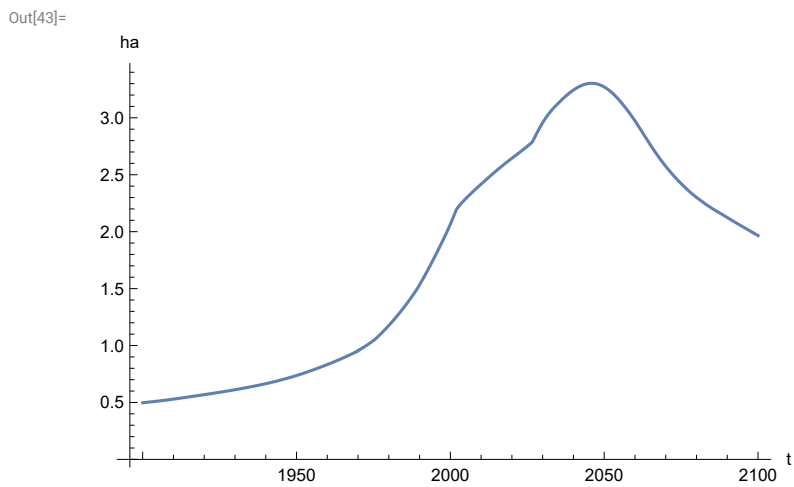
Plot the human welfare index.

```
In[42]:= SystemModelPlot[testsim1970,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



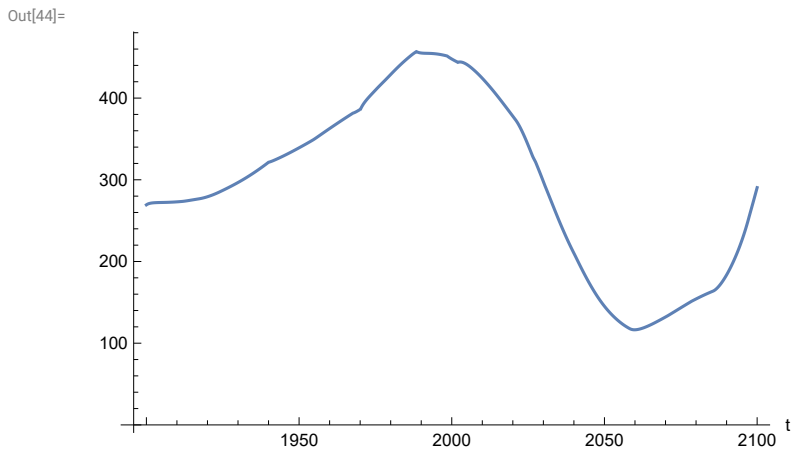
Plot the human ecological footprint, in hectares.

```
In[43]:= SystemModelPlot[testsim1970,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



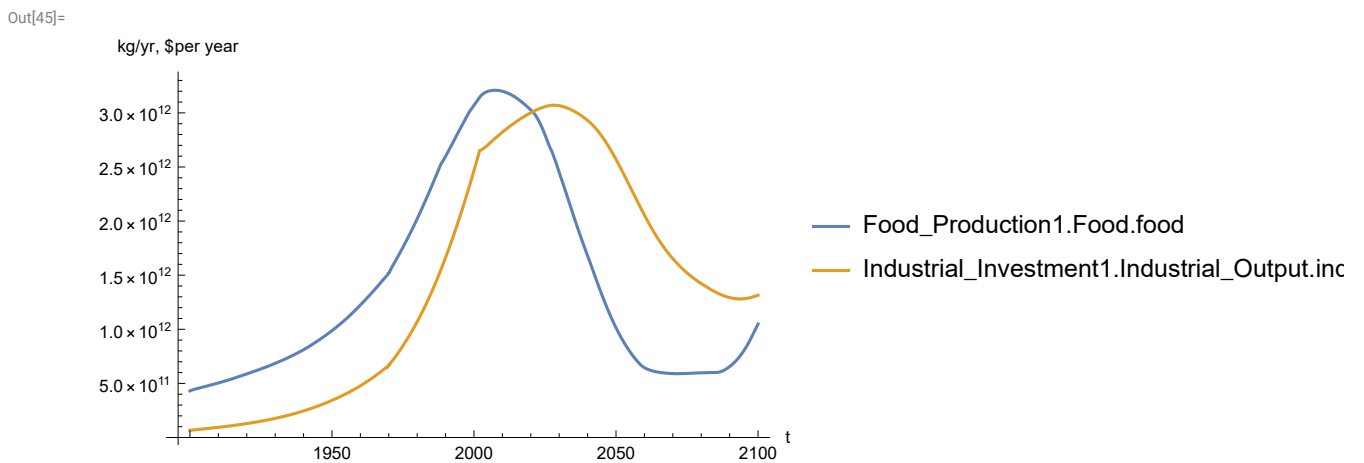
Plot per capita food production, kg/year.

```
In[44]:= SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/yr) and industrial output (in dollars).

```
In[45]:= SystemModelPlot[testsim1970, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[46]:= SystemModelPlot[testsim1970,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



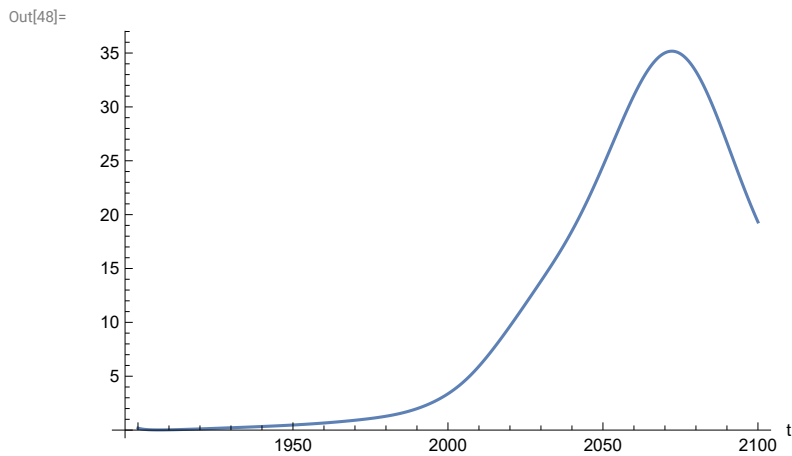
Find max and min of y values.

```
In[47]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 890.482
 Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[48]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



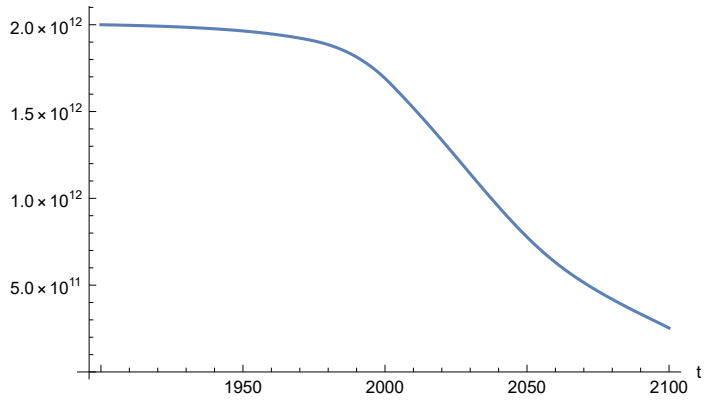
Find max and min of y values.

```
In[49]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 35.1732
 Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[50]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[50]=
```

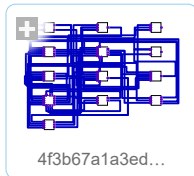


APPENDIX 94. Benchmark Scenario 8, $t_{\text{policy_year}} = 2025$. Experiment 94.

Change the value of the air pollution effect multiplier switch time $t_{\text{policy_year}}$, to calendar year 2025, and execute the resulting scenario, plotting the variables shown in Figure 2.

```
In[51]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```

```
Out[51]=
```



```
In[52]:= testsim = SystemModelSimulate[newmysim]
```

```
Out[52]=
```

```
SystemModelSimulationData [ Model: W4f3b67a1a3ed42a790c99b5cdc56d0a8  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of $t_{\text{policy_year}}$.

```
In[53]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
```

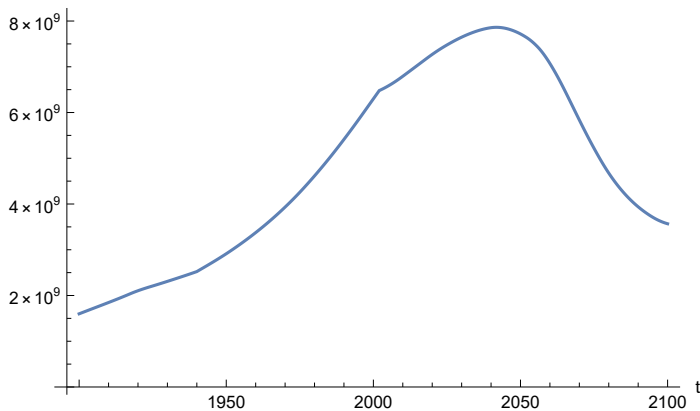
```
Out[53]=
```

```
{t_policy_year → 2025}
```

Plot the world population, people.

```
In[54]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[54]=
```

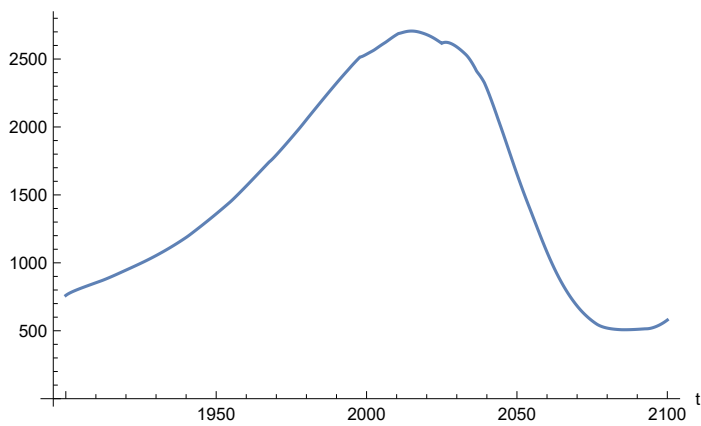


Find max and min of y values.

```
In[55]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.86244 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

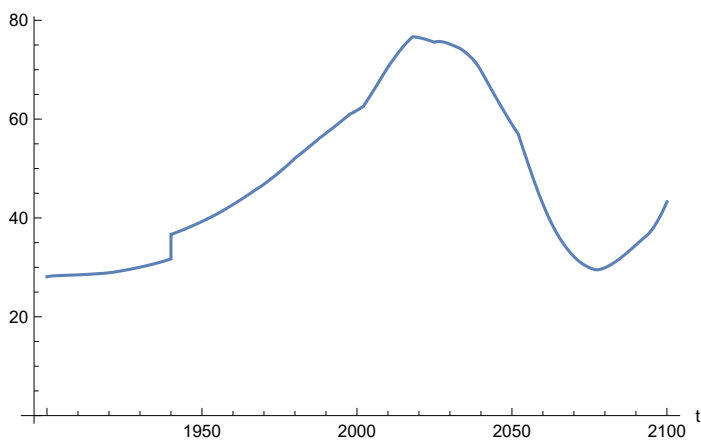
Plot land yield.

```
In[56]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[56]=
```



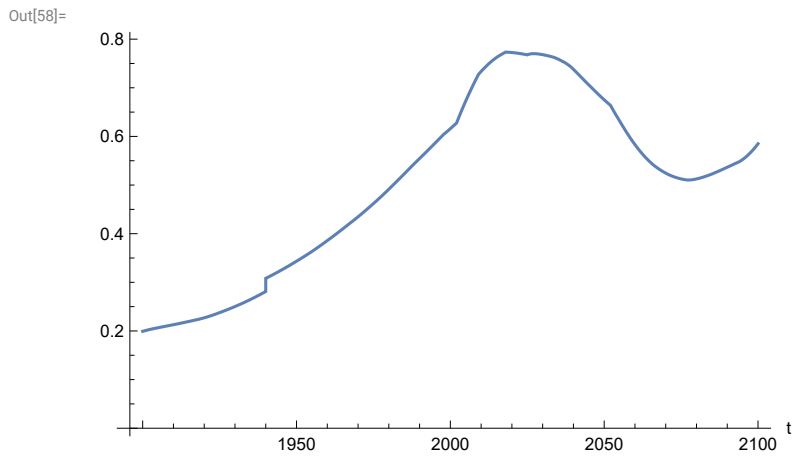
Plot life expectancy, in years.

```
In[57]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[57]=
```



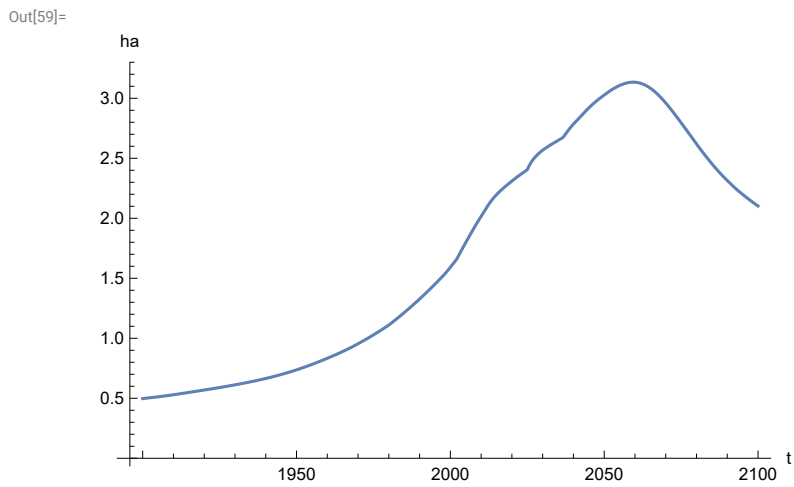
Plot the human welfare index.

```
In[58]:= SystemModelPlot[testsim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot the human ecological footprint, in hectares.

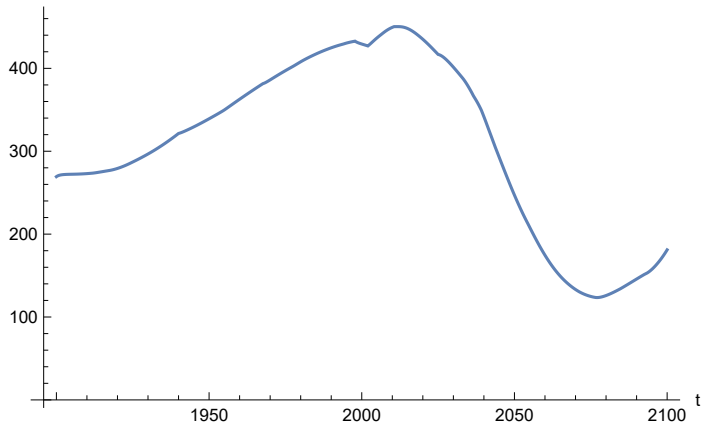
```
In[59]:= SystemModelPlot[testsim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot per capita food production, kg/year.

In[60]:= **SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]**

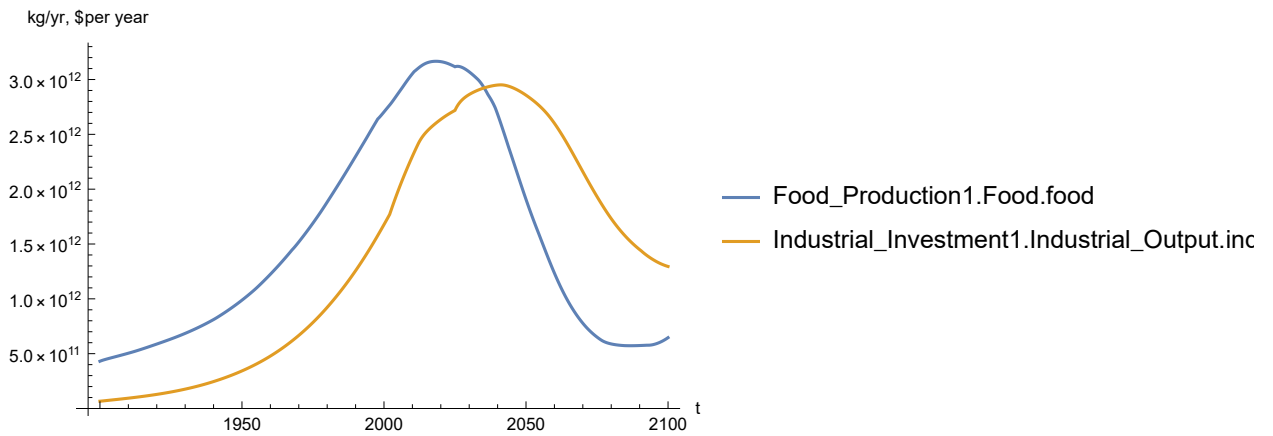
Out[60]=



Plot total food production (kg/yr) and industrial output (in dollars).

In[61]:= **SystemModelPlot[testsim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[61]=



Plot consolidated industrial output per capita (dollars/year).

```
In[62]:= SystemModelPlot[testsim,
{"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

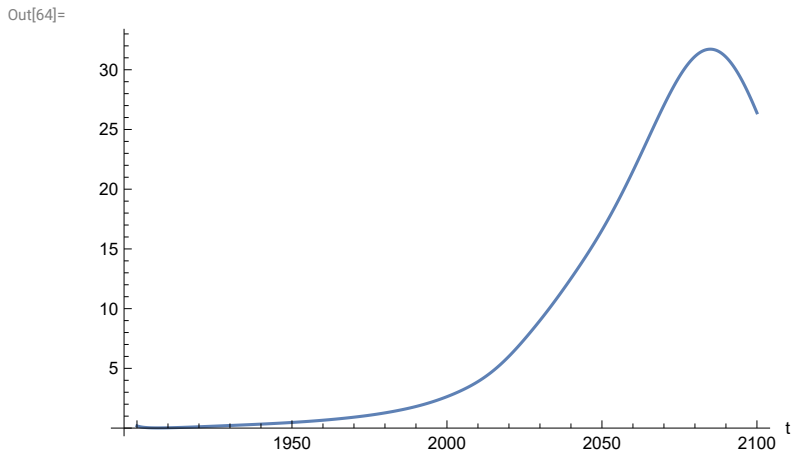


Find max and min of y values.

```
In[63]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 882.101
Minimum is 87.4451
```

Plot persistent pollution index (normalized to 1970 value).

```
In[64]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

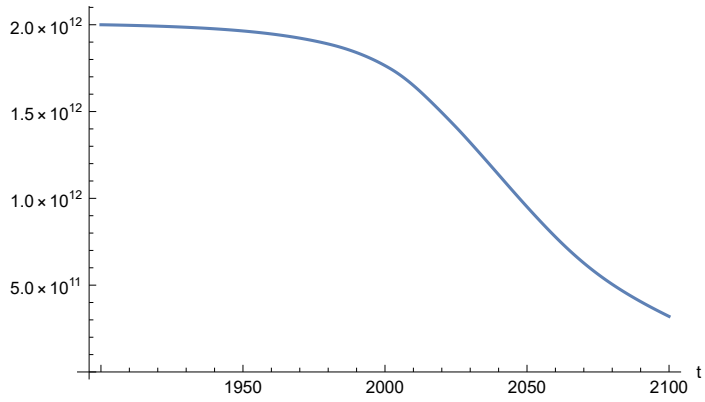


Find max and min of y values.

```
In[65]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 31.7222
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[66]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[66]=
```



APPENDIX 95. BENCHMARK SCENARIO 8, Experiment 95. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 30 July 2022/1520 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

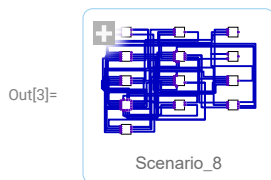
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

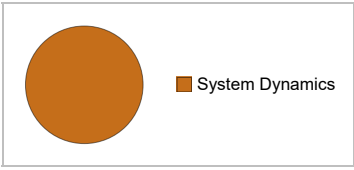
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 8.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_8"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_8
	D	More abundant non-recoverable natural resources, birth control, and stable industrial output
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

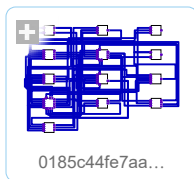
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

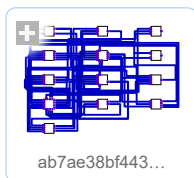
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

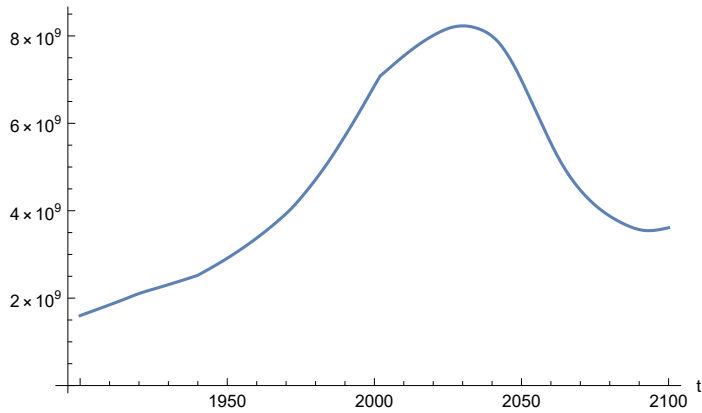
```
Out[21]=
```

```
SystemModelSimulationData [   Model: Wab7ae38bf443469684060e178d745f3e
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

In[22]:= **SystemModelPlot**[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]

Out[22]=



Find max and min of population values.

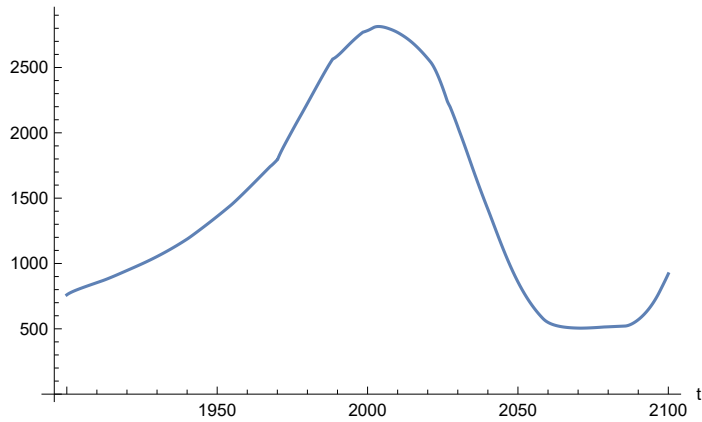
In[23]:= **MinAndMax**[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]

Maximum is 8.22943×10^9

Minimum is 1.6×10^9

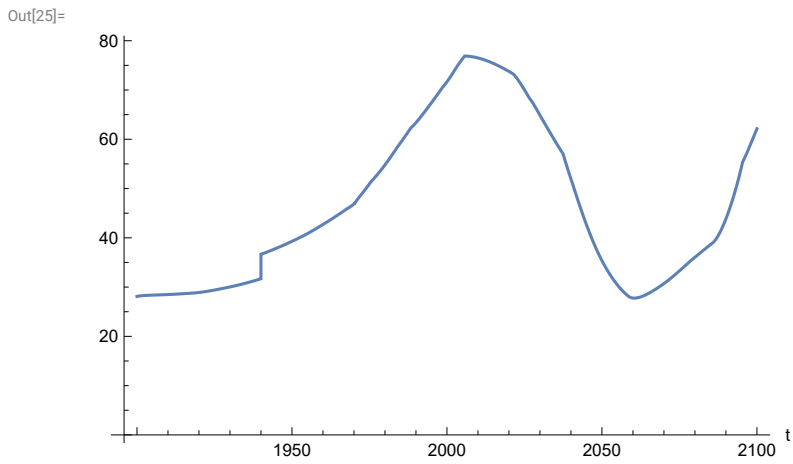
In[24]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

Out[24]=



Plot life expectancy, years.

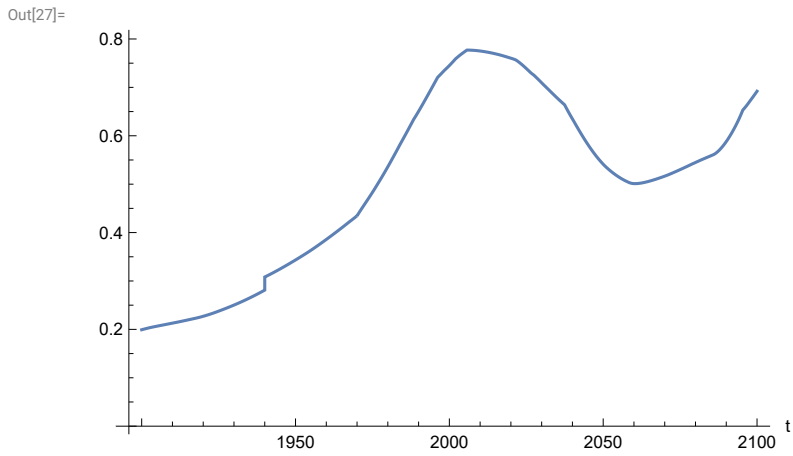
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```



```
In[26]:=
```

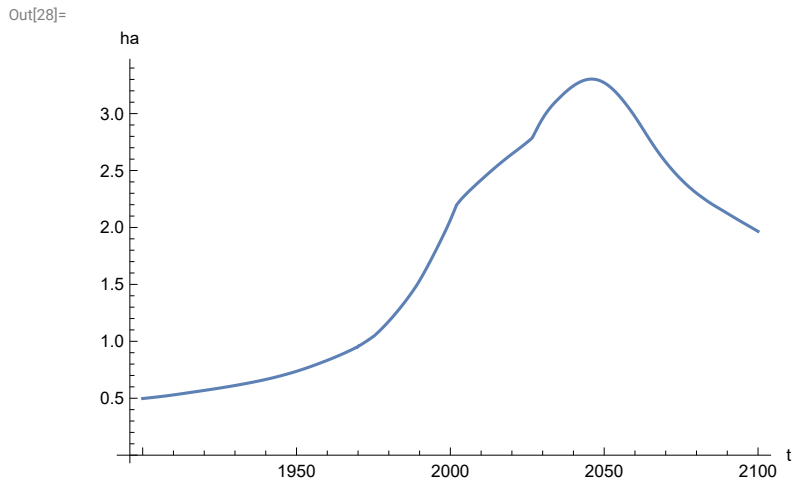
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



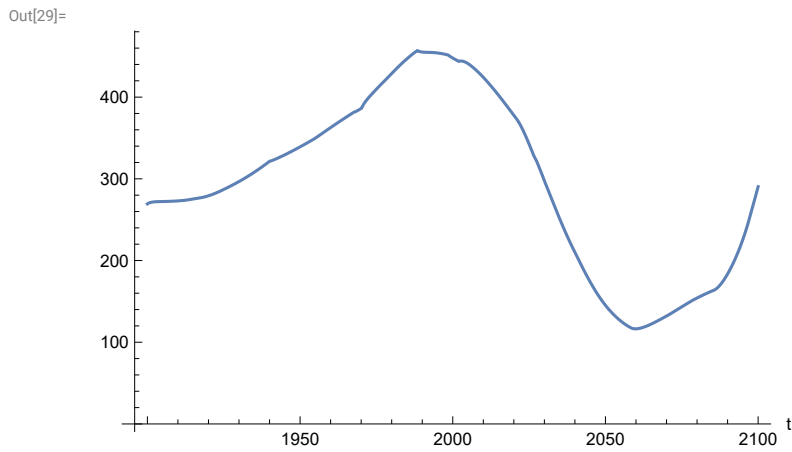
Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



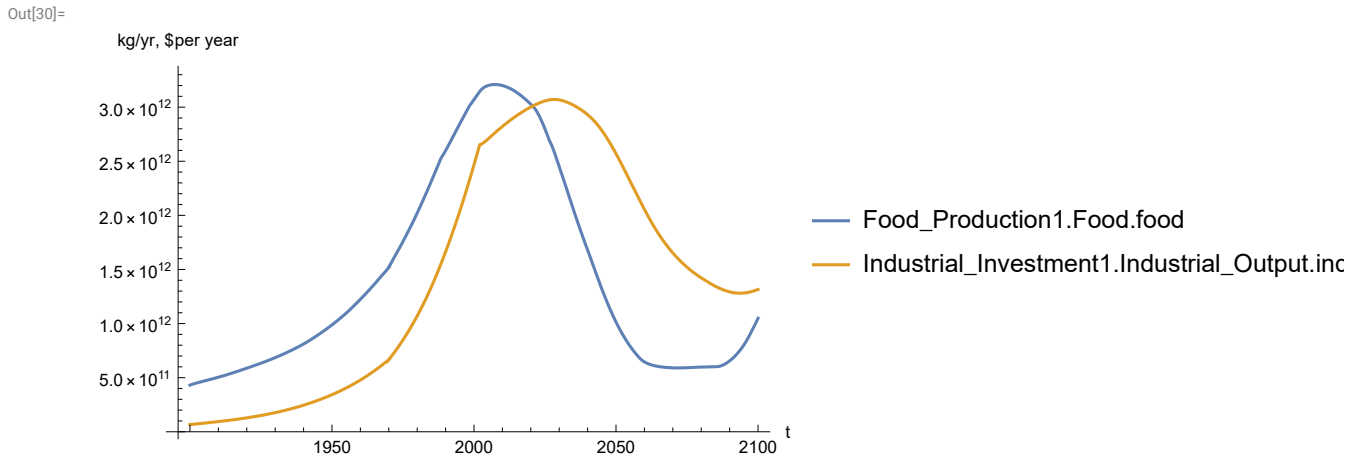
Plot food production per capita (kg/year).

```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



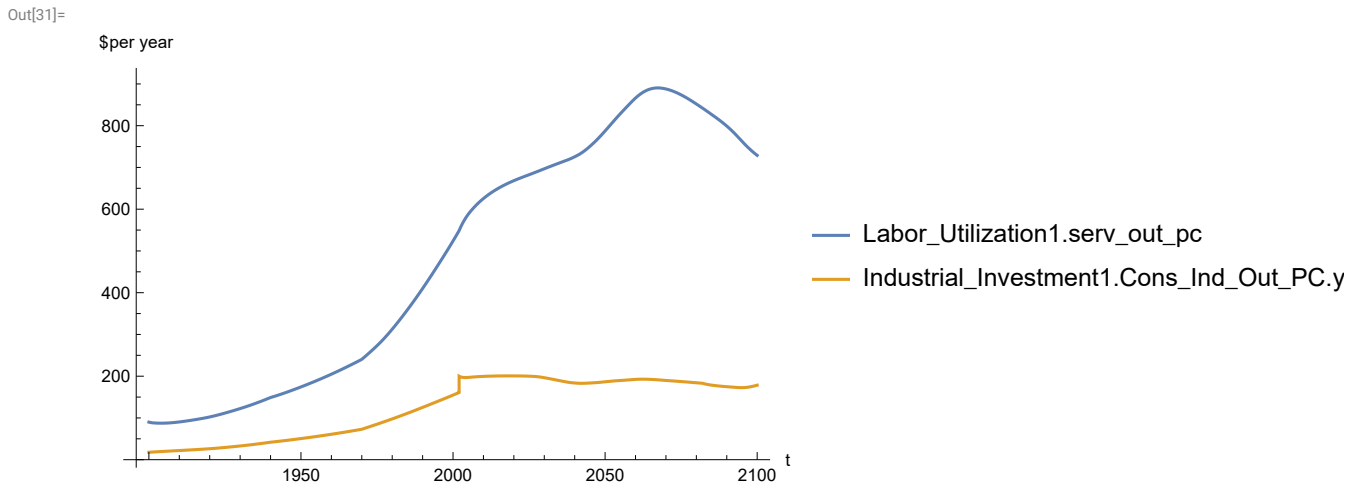
Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



Find max and min of y values.

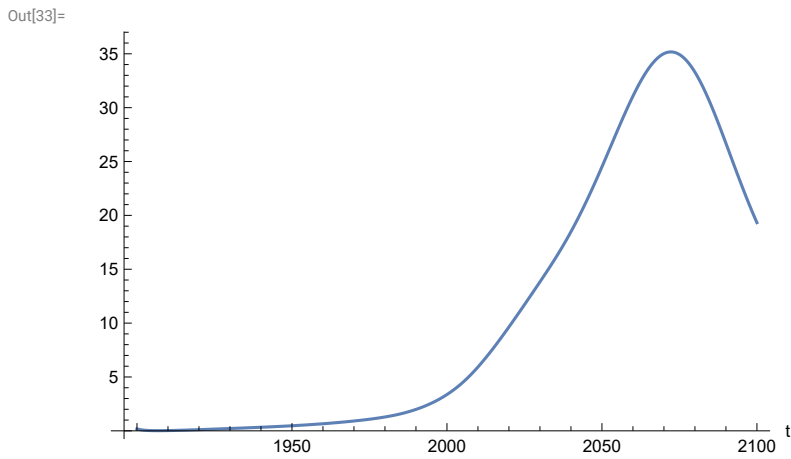
```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 890.482

Minimum is 87.4451

Plot persistent pollution index.

In[33]:= **SystemModelPlot**[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]



Find max and min of y values.

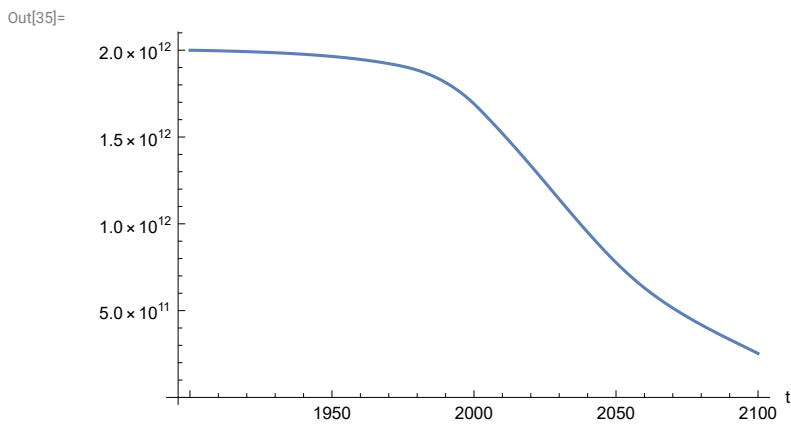
In[34]:= **MinAndMax**[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]

Maximum is 35.1732

Minimum is 0.0150765

Plot non-renewable resources remaining.

In[35]:= **SystemModelPlot**[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]

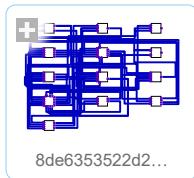


APPENDIX 96. LE/1.001, t_policy_year = 2025. Baseline Scenario 8, Experiment 96.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure default _Serv_2.y_vals

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

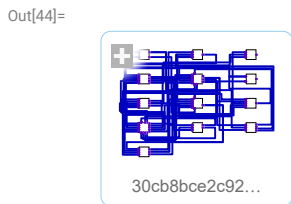
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```



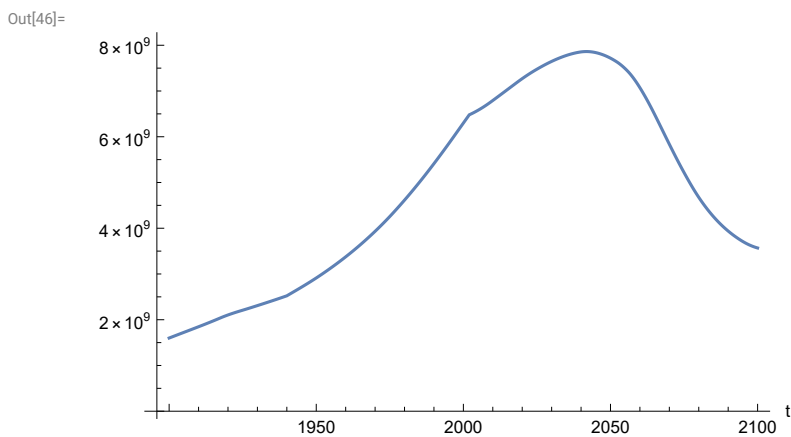
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W30cb8bce2c924ab291f110300136bb94
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

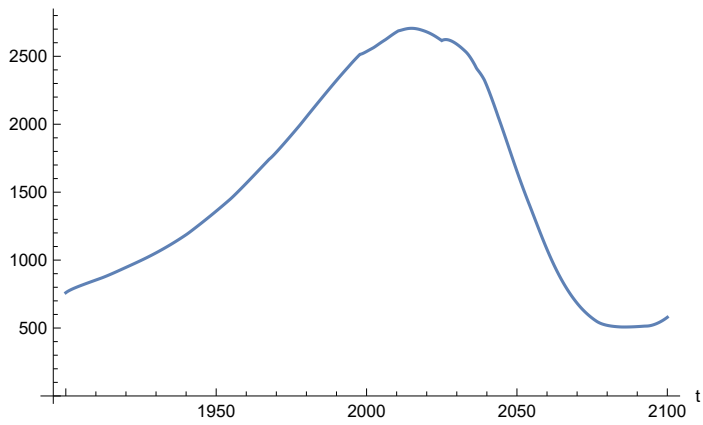
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.86244×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

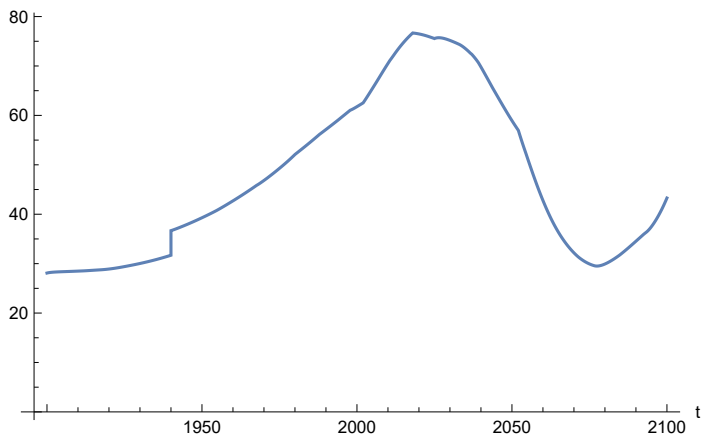
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

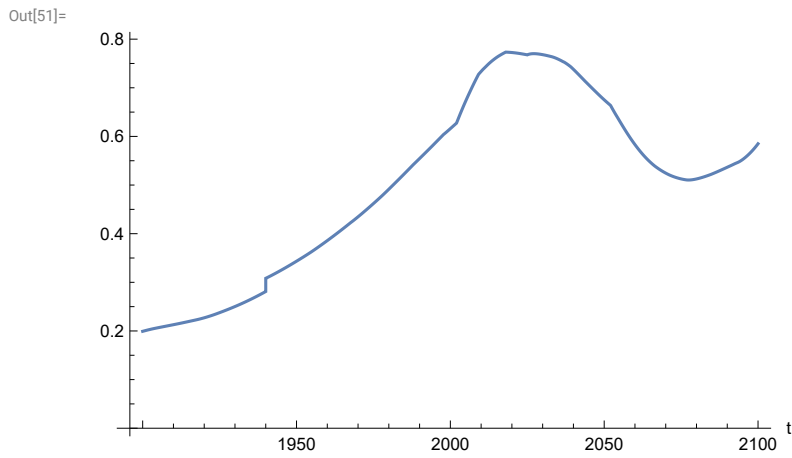
Out[49]=



In[50]=

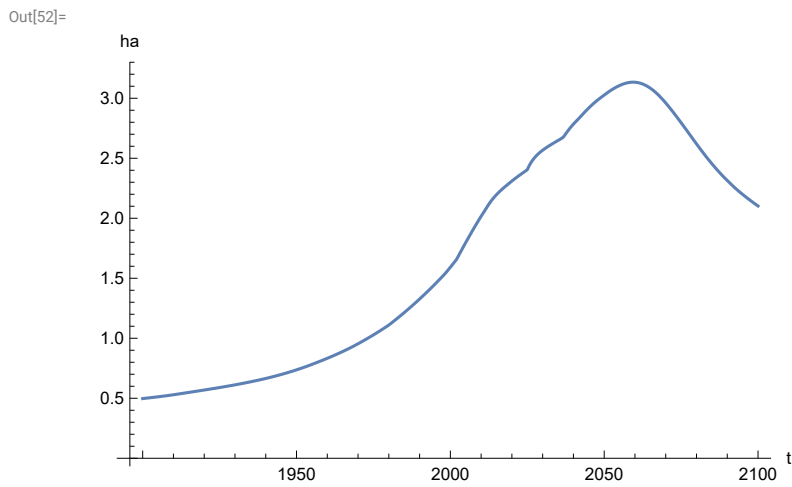
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

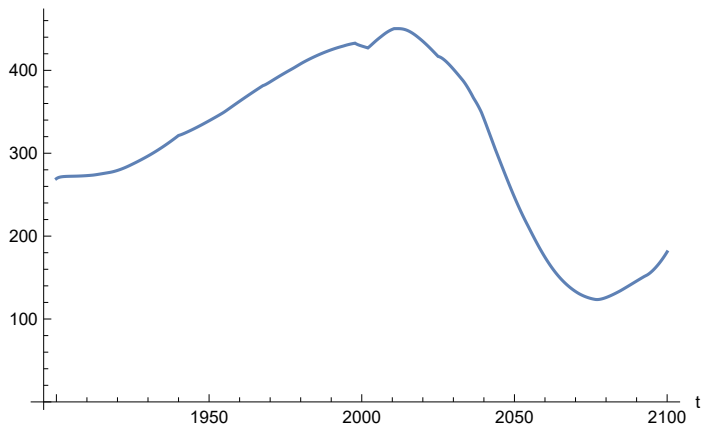
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

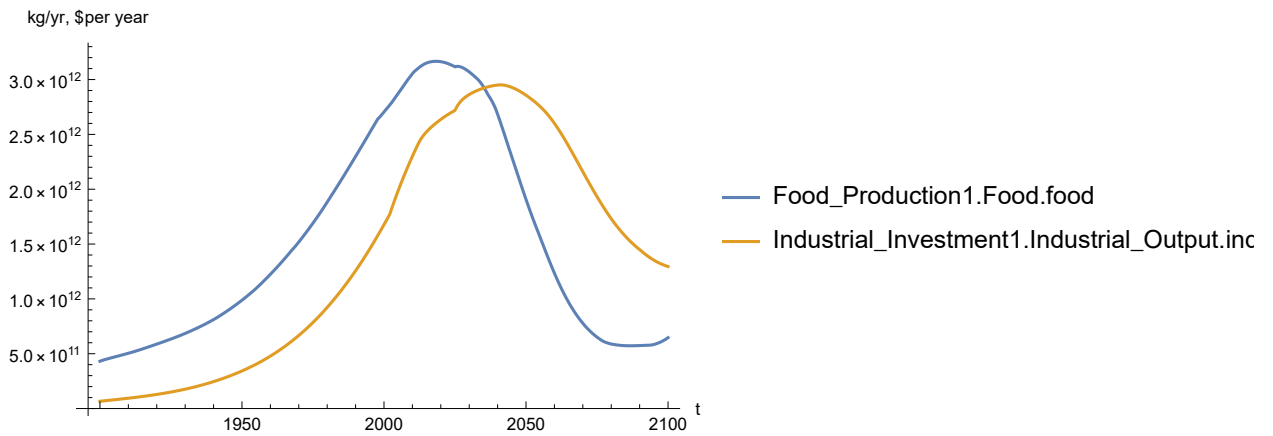
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

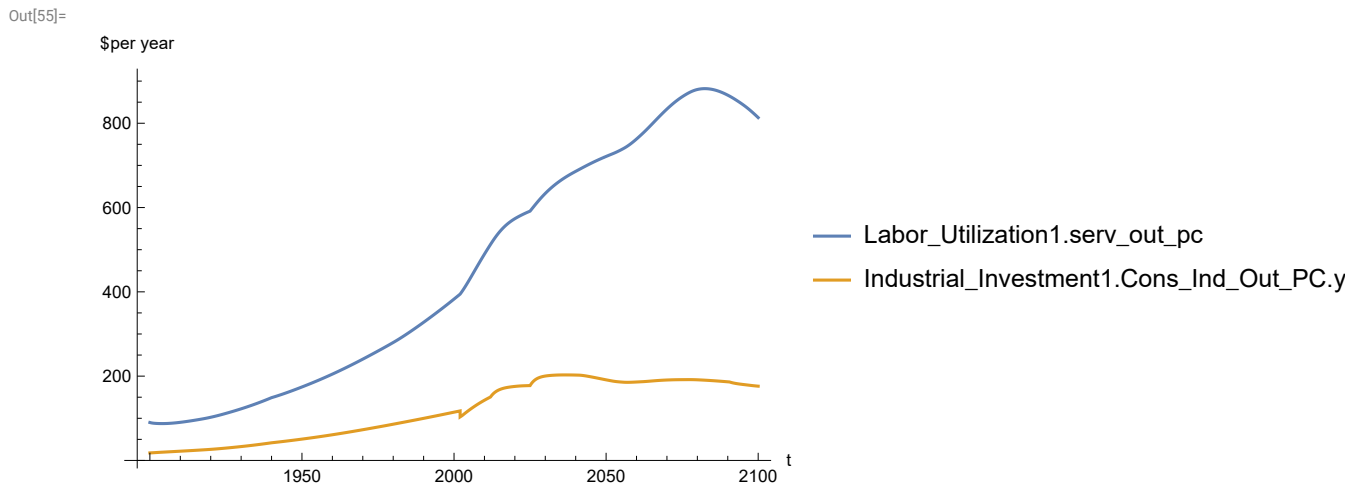
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

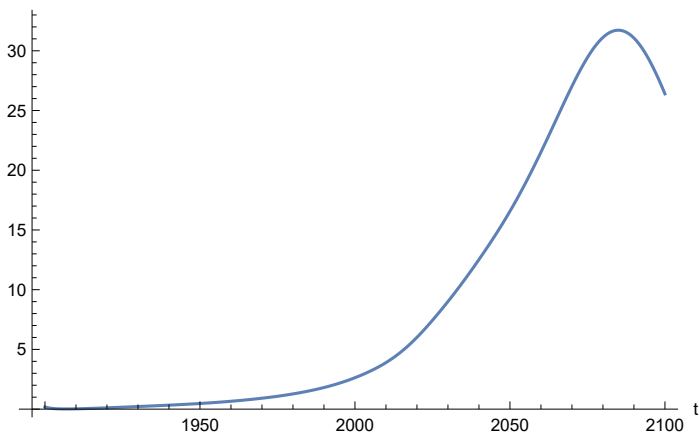


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 882.101
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



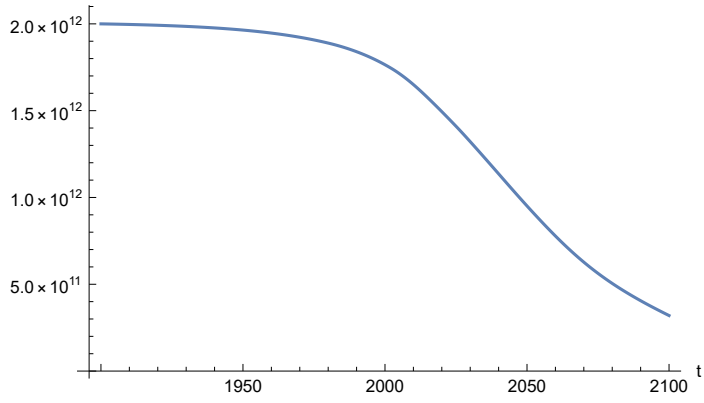
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 31.7222
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

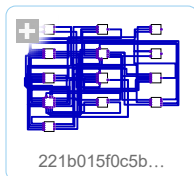


APPENDIX 97. LE/1.01, t_policy_year = 1970. Baseline Scenario 8, Experiment 97.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

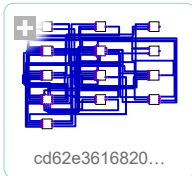
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

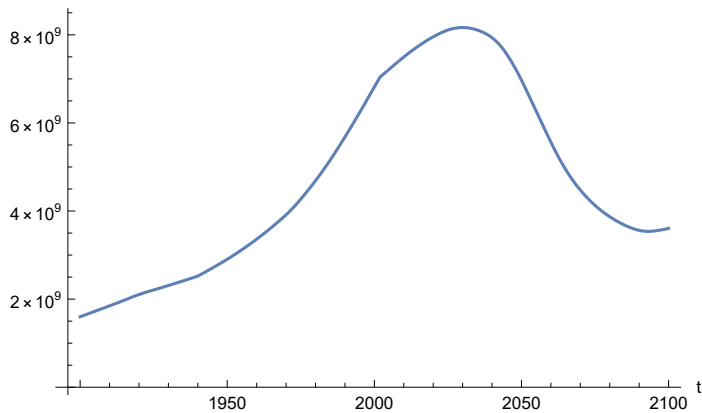
```
Out[69]=
```

```
SystemModelSimulationData [ {  Model: Wcd62e361682041fca094b0b8321e8031
  Time: 1.90 × 103 to 2.10 × 103 } ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

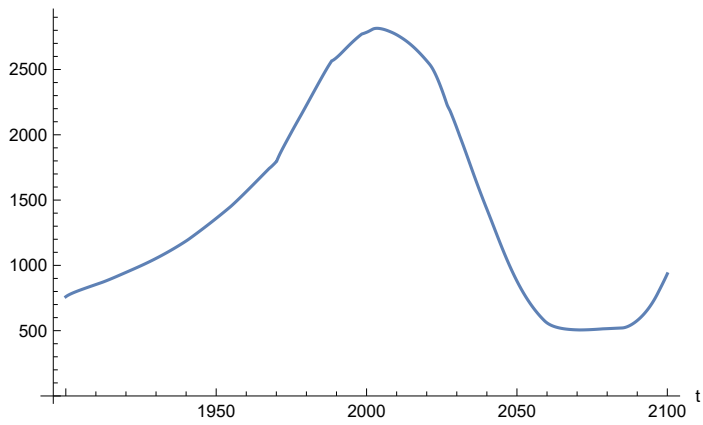
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.16544 × 109
```

```
Minimum is 1.6 × 109
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

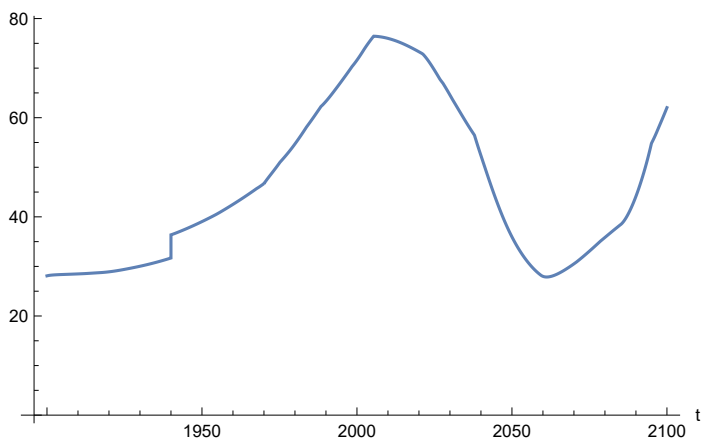
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

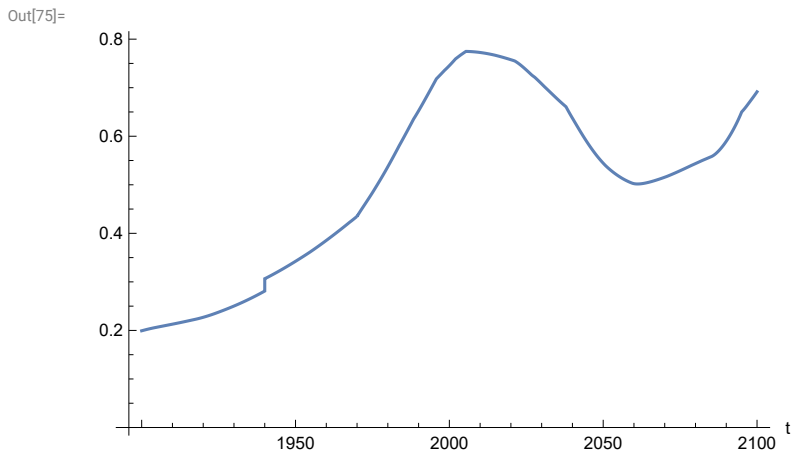
Out[73]=



In[74]:=

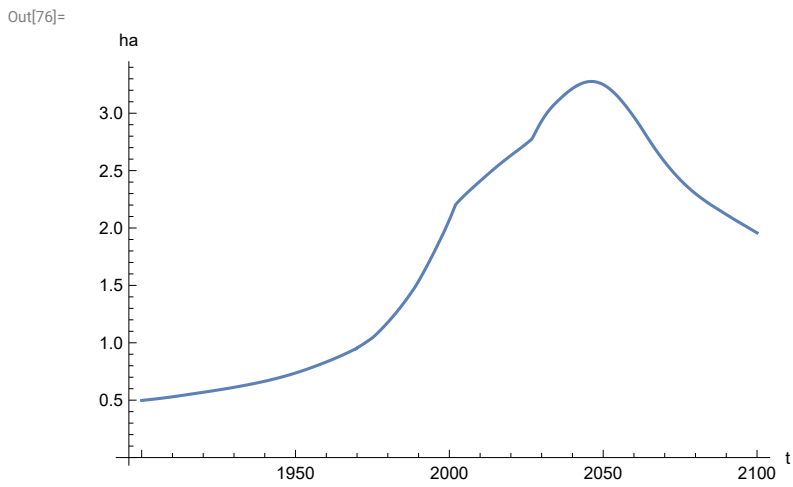
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

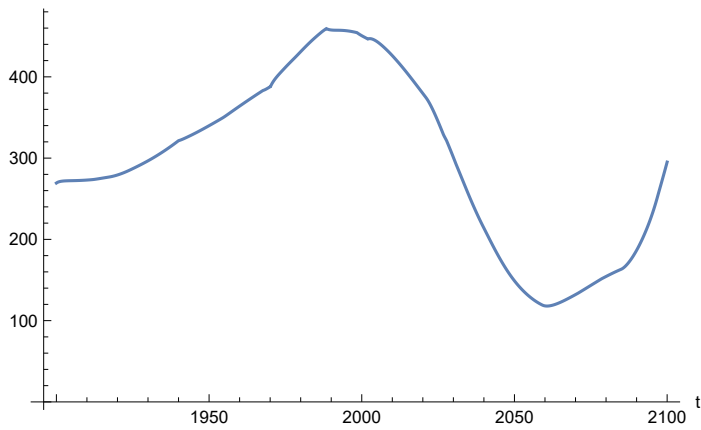
```
In[76]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

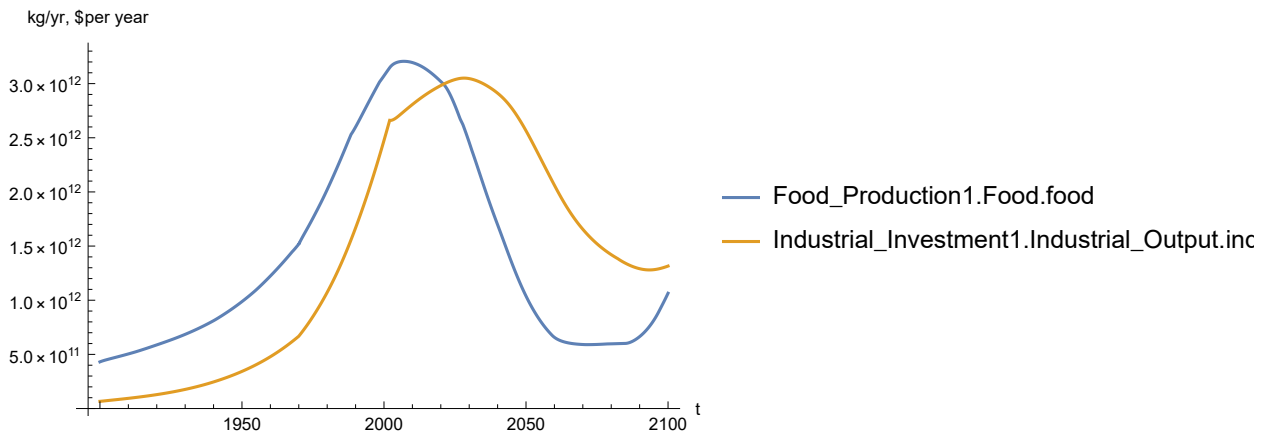
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

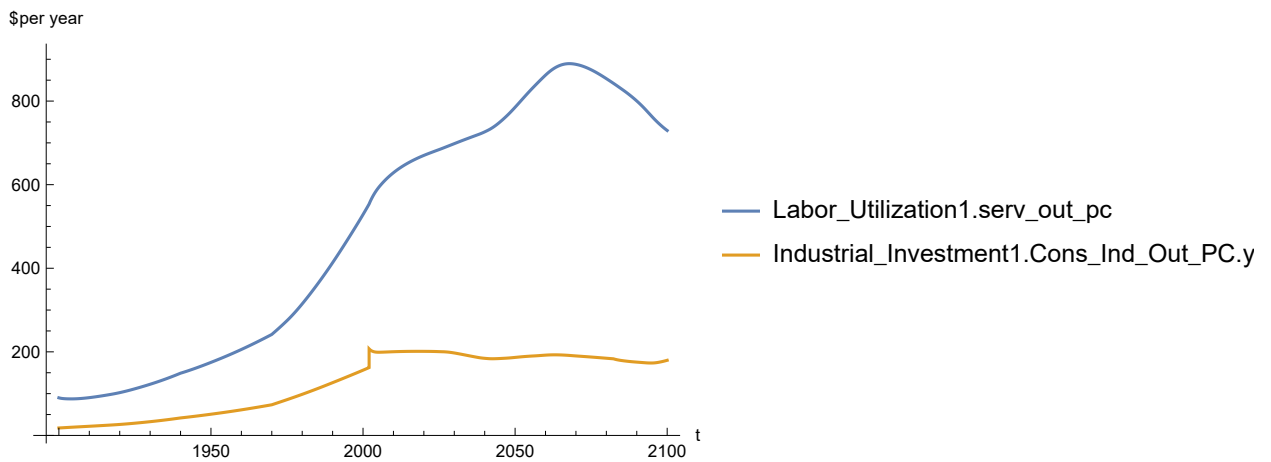
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

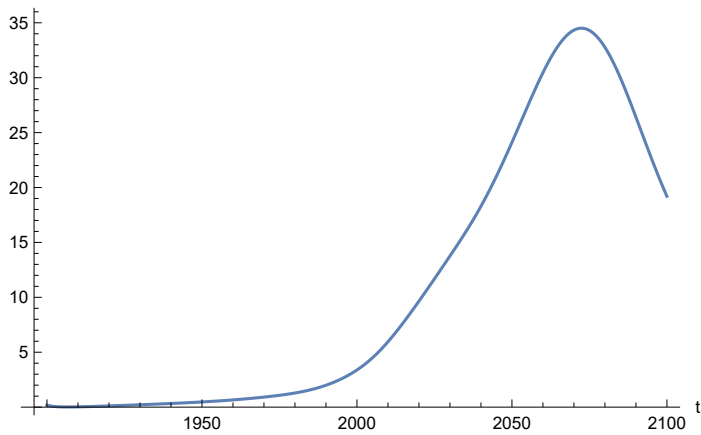
Maximum is 889.556

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

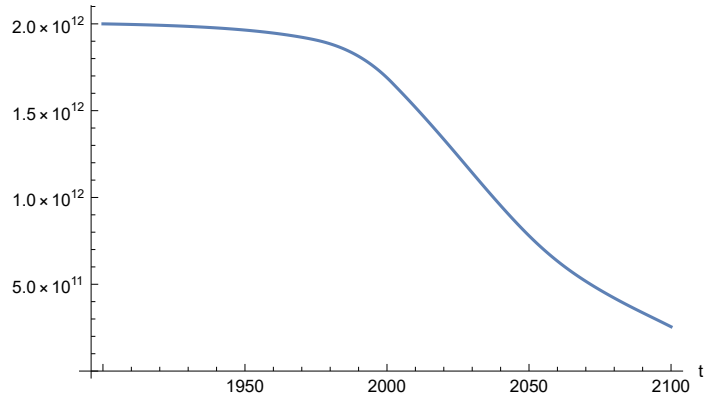
Maximum is 34.5064

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

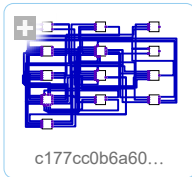
Out[83]=



APPENDIX 98. Baseline Scenario 8, Experiment 98. LE = LE/1.01, t_policy_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

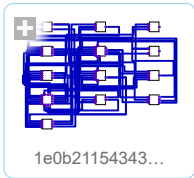
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```


Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



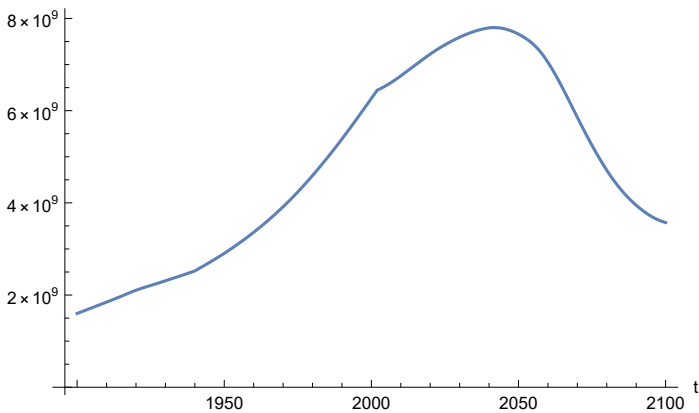
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

SystemModelSimulationData [ Model: W1e0b211543434607b140a7490a6307d5
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

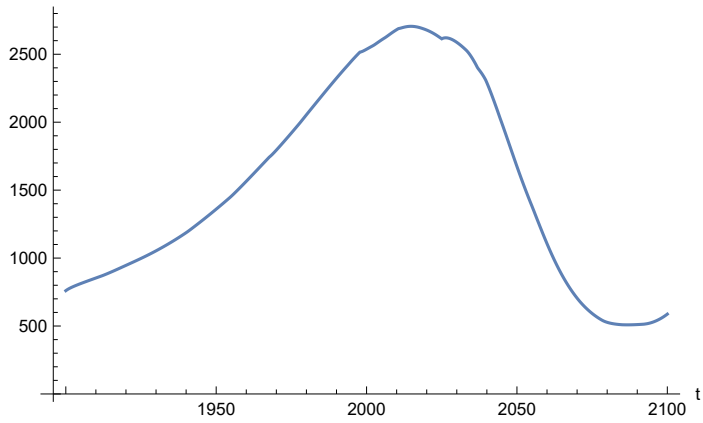


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.80275 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

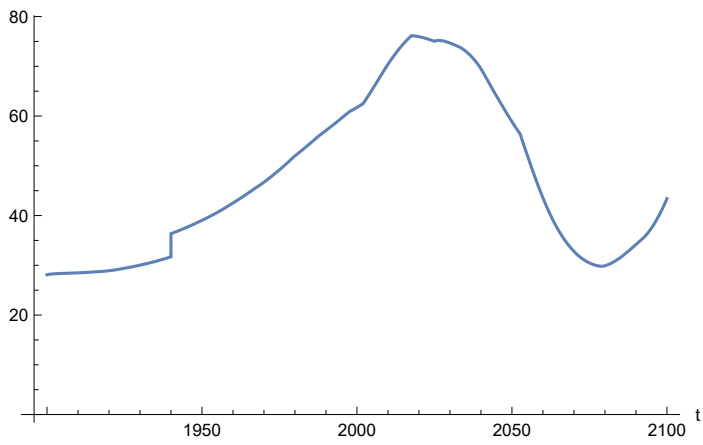
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

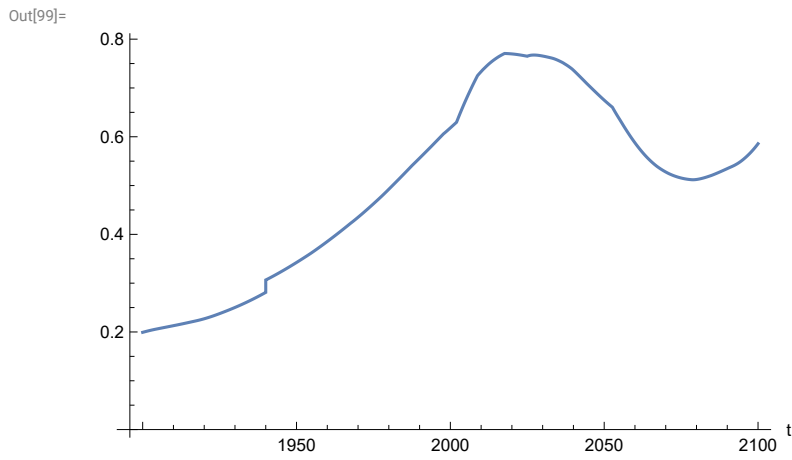
Out[97]=



In[98]=

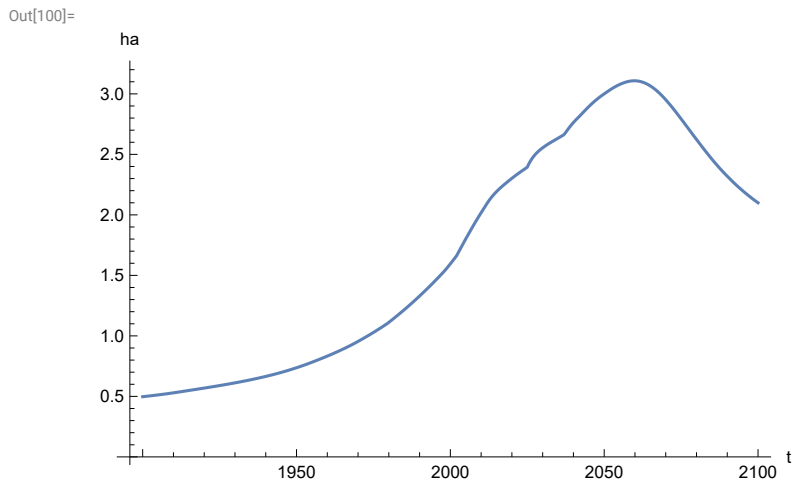
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

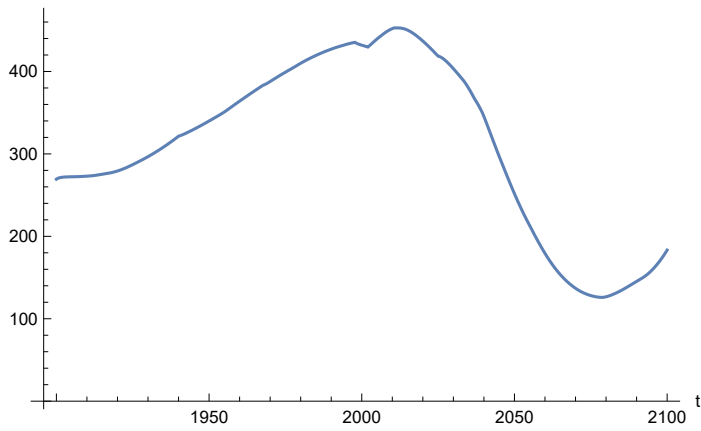


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

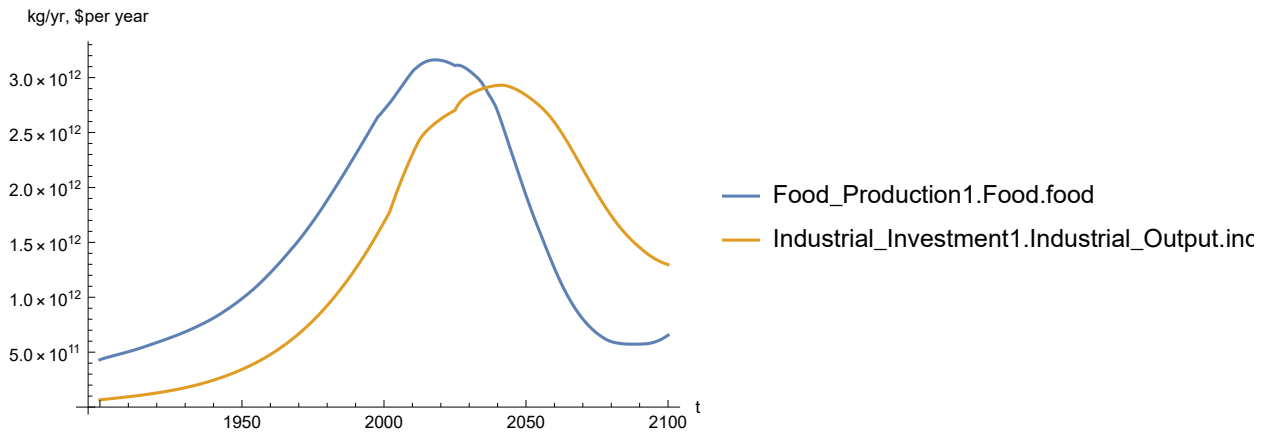


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

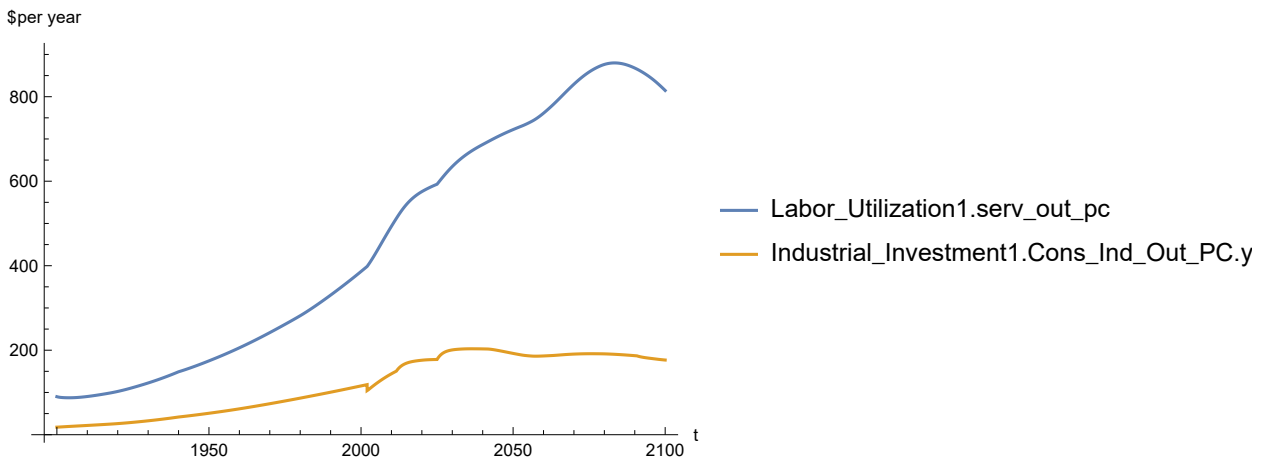


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

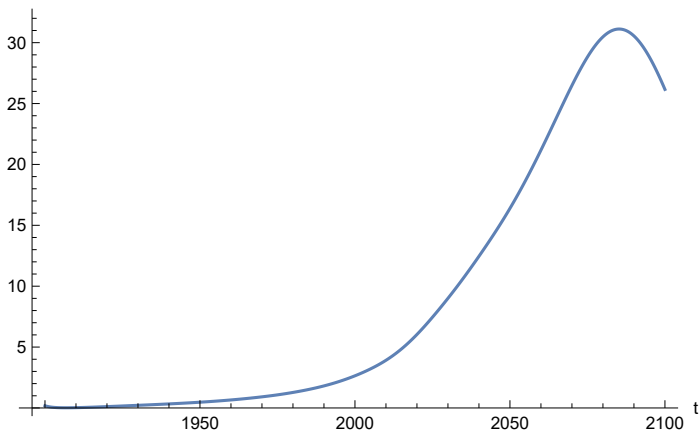
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 879.963
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 31.1193

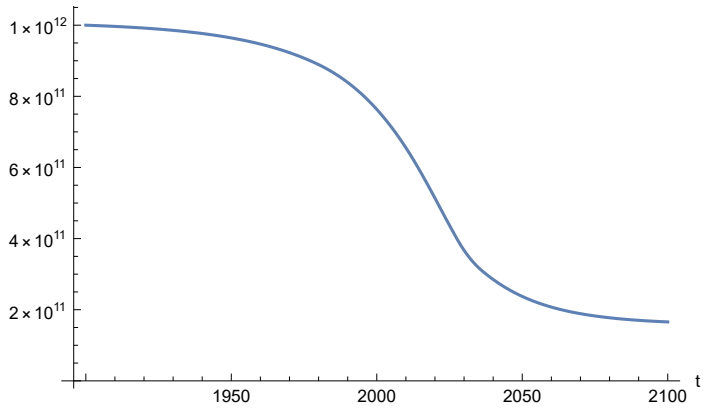
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



**APPENDIX 99. BENCHMARK SCENARIO 8, Experiment 99. LE = LE/1.03, t_policy_year = 1970.
Last modified: 25 July 2022/1640 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

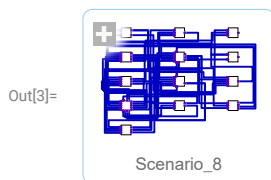
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

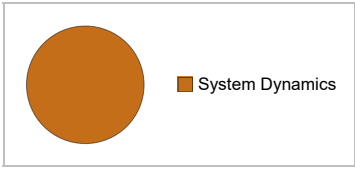
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 8.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_8"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_8
	Description	More abundant non-recoverable natural resources, birth control, and stable industrial output
	Simulation Interval	True
	Plot	0
	Cell Count	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

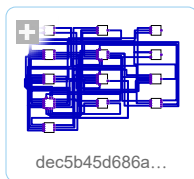
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

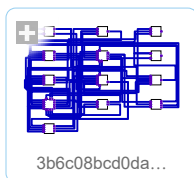
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

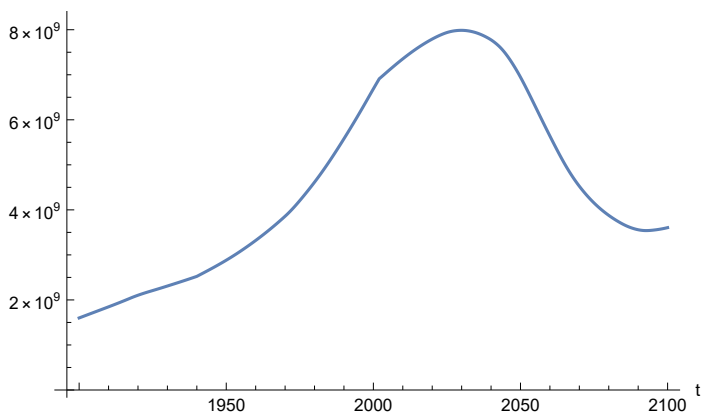
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W3b6c08bcd0da45f28d9bc0d0560163f5  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

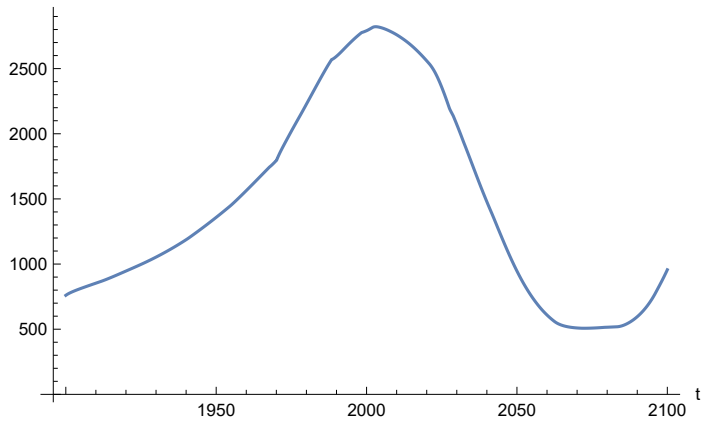
```
Out[22]=
```



Find max and min of population values.

```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.9867 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

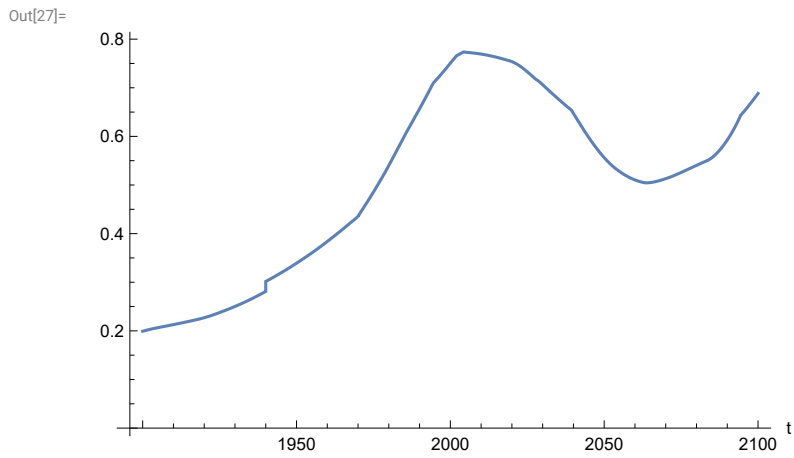
```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```



```
In[26]:=
```

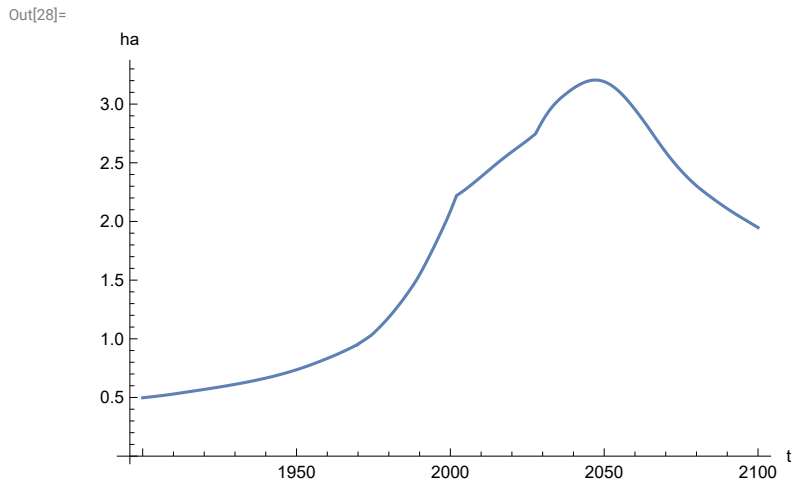
Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



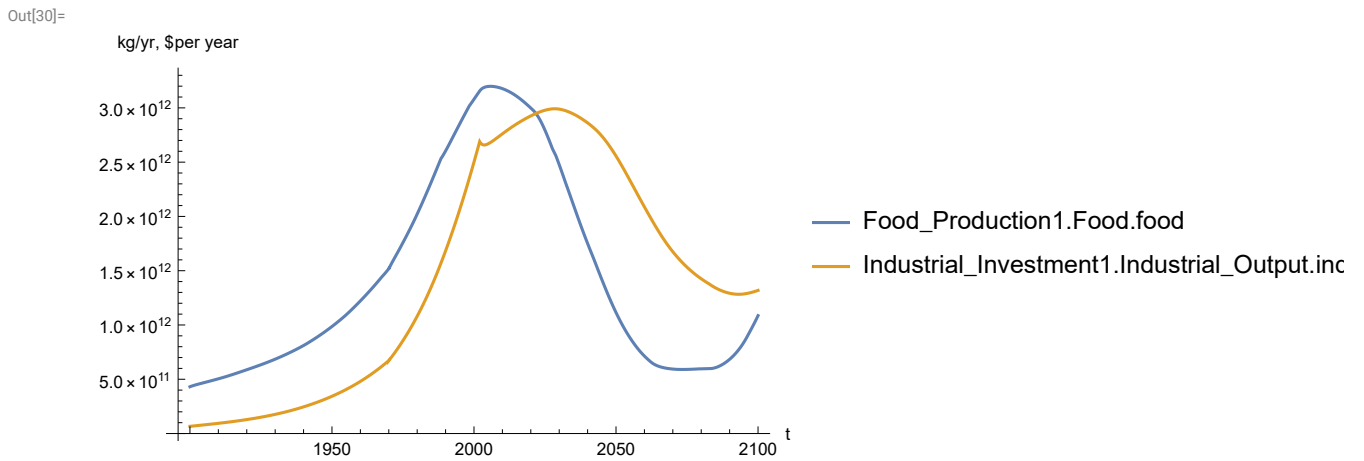
Plot food production per capita (kg/year).

```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

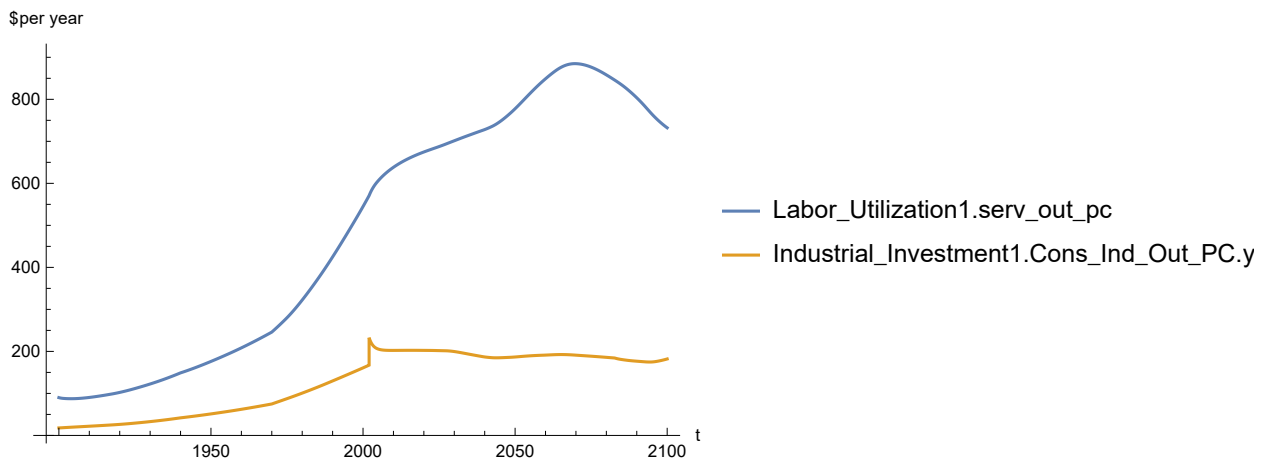
```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

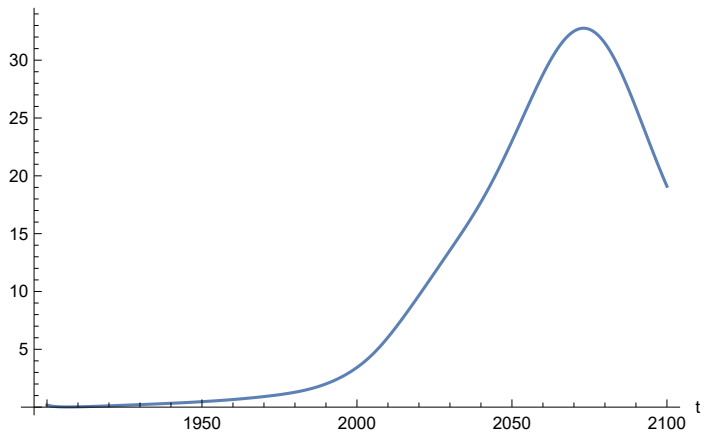
Maximum is 884.922

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[33]=



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

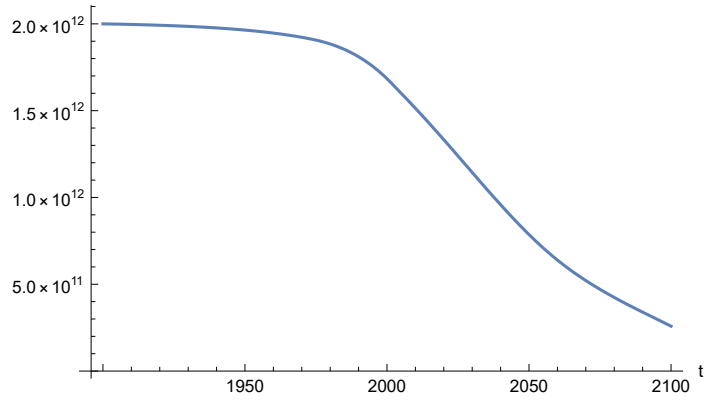
Maximum is 32.7634

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

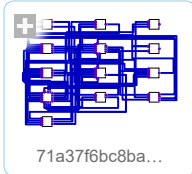


APPENDIX 100. LE/1.03, t_policy_year = 2025. Baseline Scenario 8, Experiment 100.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[  
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →  
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}} |>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim][  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim][  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim][  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim][  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim][  
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

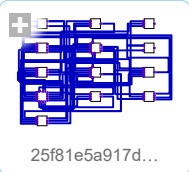
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

Out[44]=  25f81e5a917d...

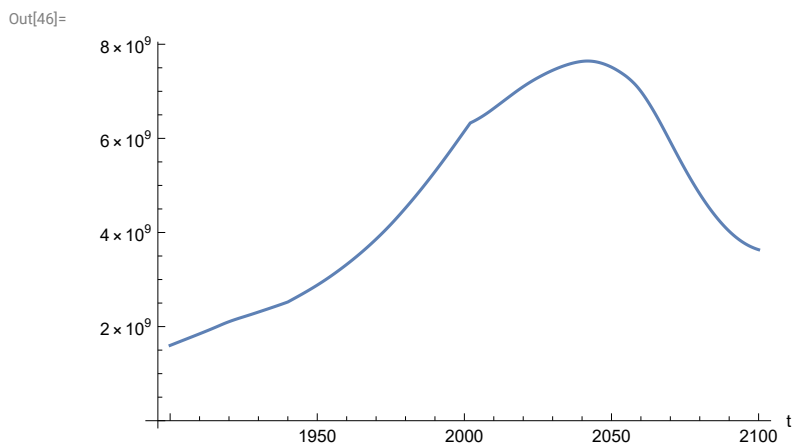
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W25f81e5a917d42d59c66e50a75f41908
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



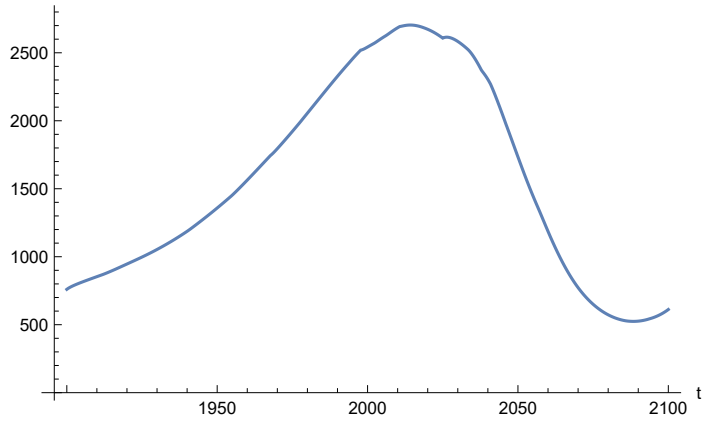
Find max and min of population values.

```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.64349×10^9
Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

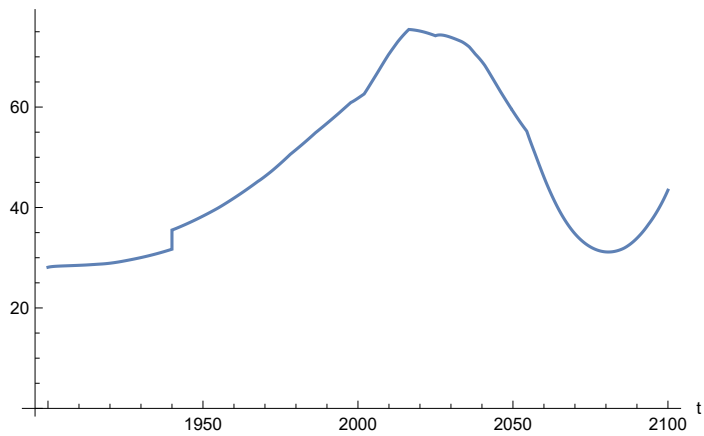
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

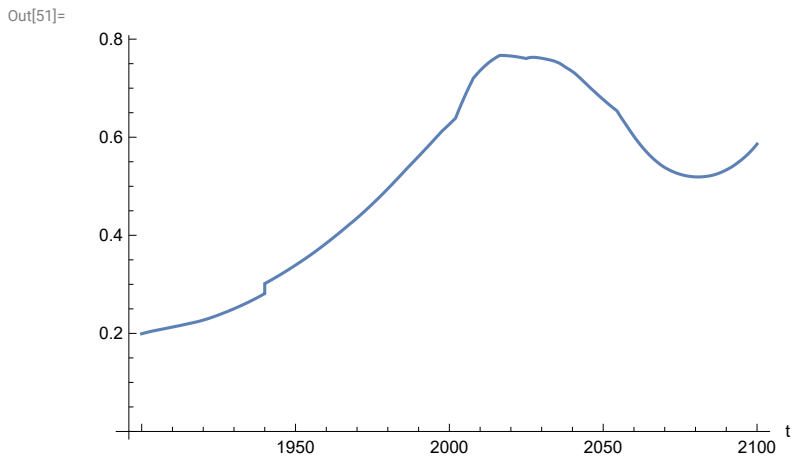
Out[49]=



In[50]=

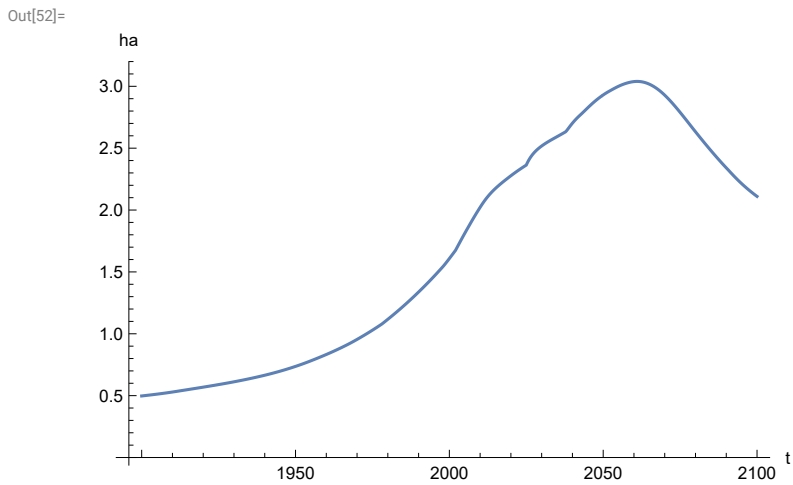
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

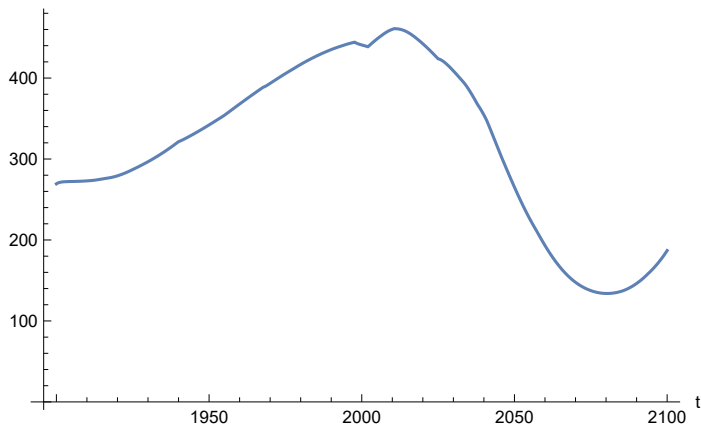
```
In[52]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[53]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

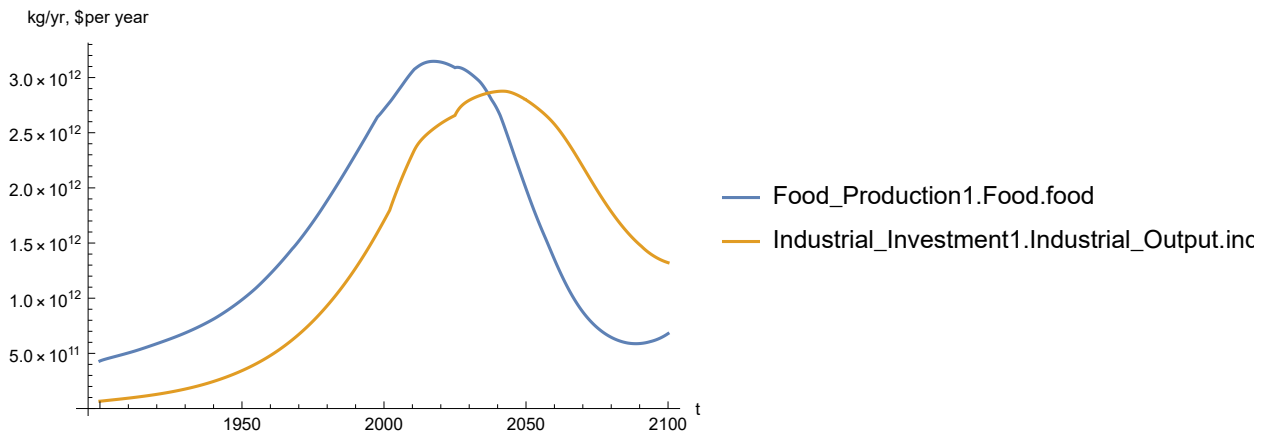
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

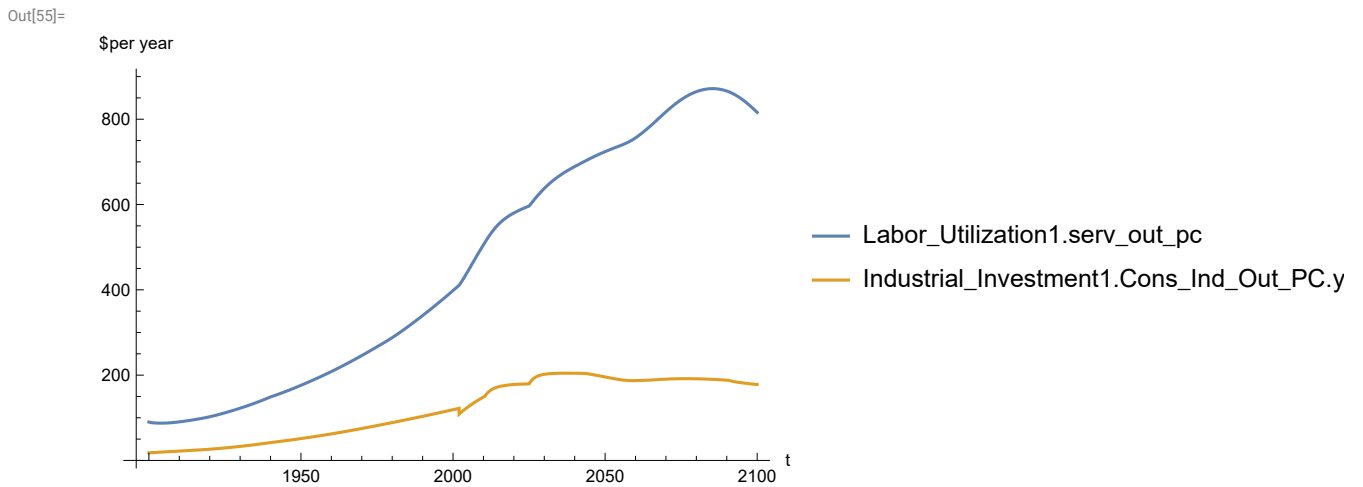
```
In[54]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

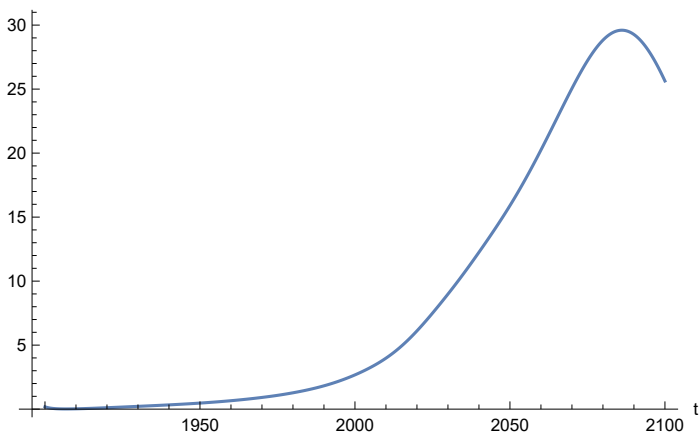


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 871.704
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



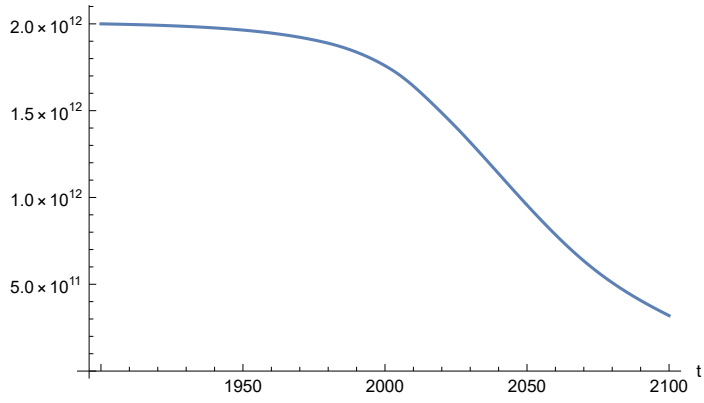
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 29.6003
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

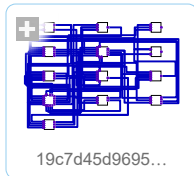


APPENDIX 101. LE/1.05, t_policy_year = 1970. Baseline Scenario 8, Experiment 101.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}} |>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

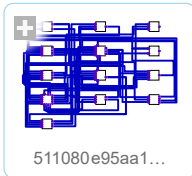
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

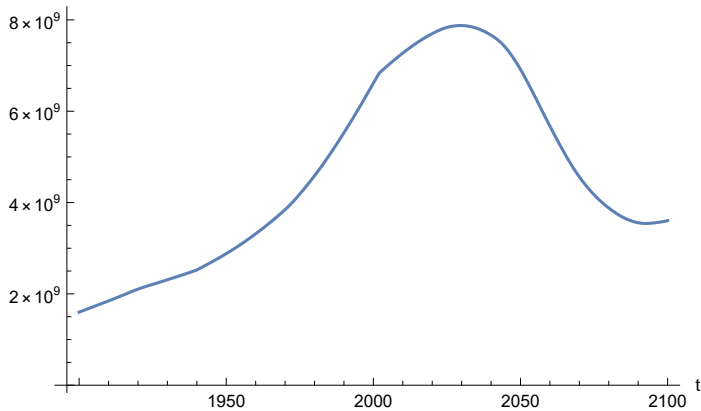
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W511080e95aa14f6f900d60611fe94505  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

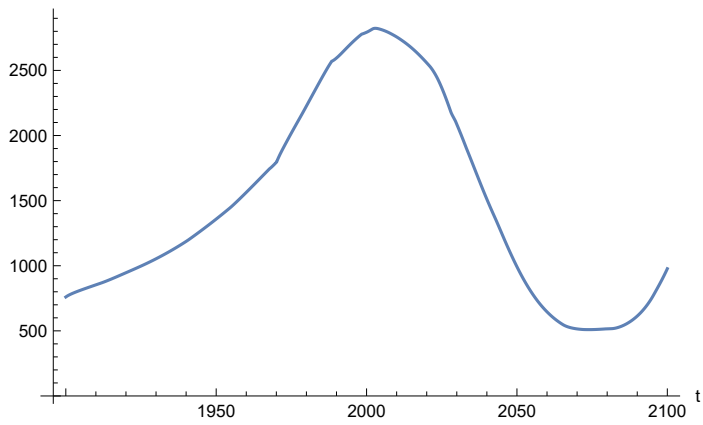
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.87601 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

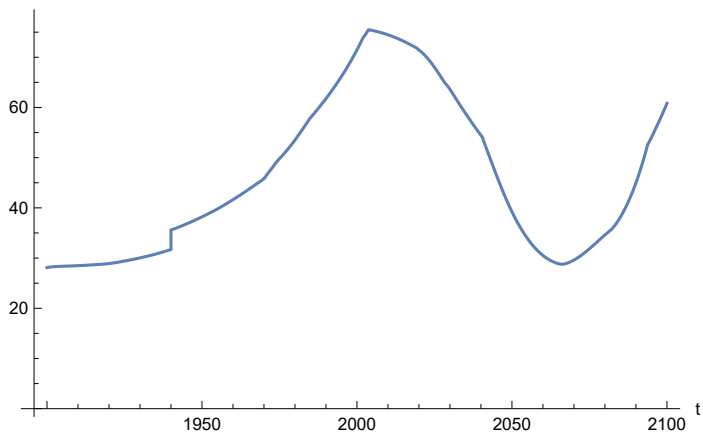
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

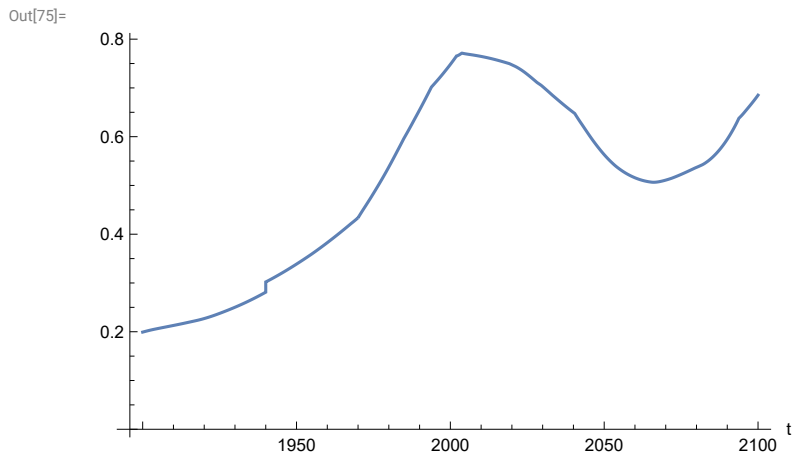
Out[73]=



In[74]:=

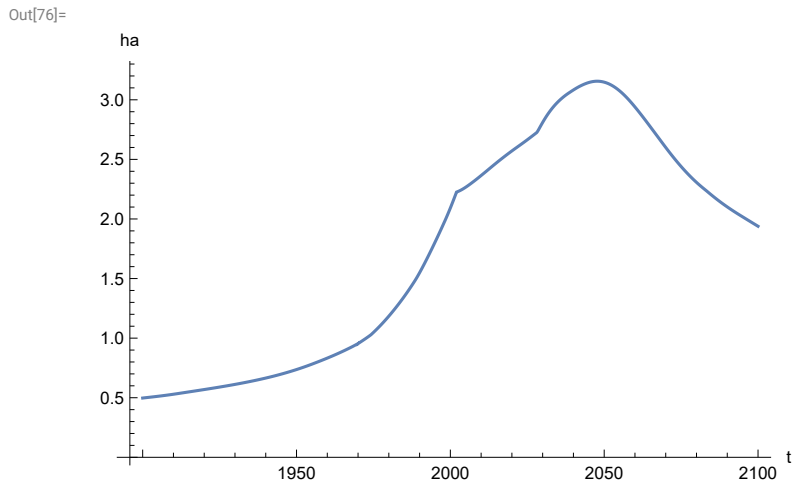
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



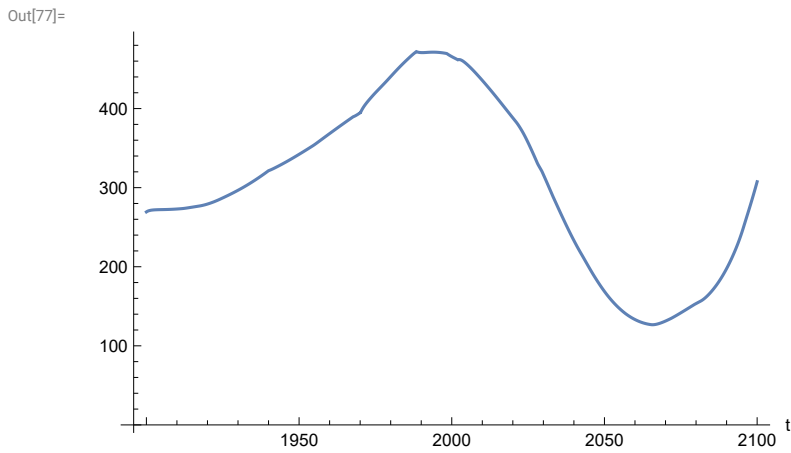
Plot per capita ecological footprint, hectares.

```
In[76]:= SystemModelPlot[basesim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



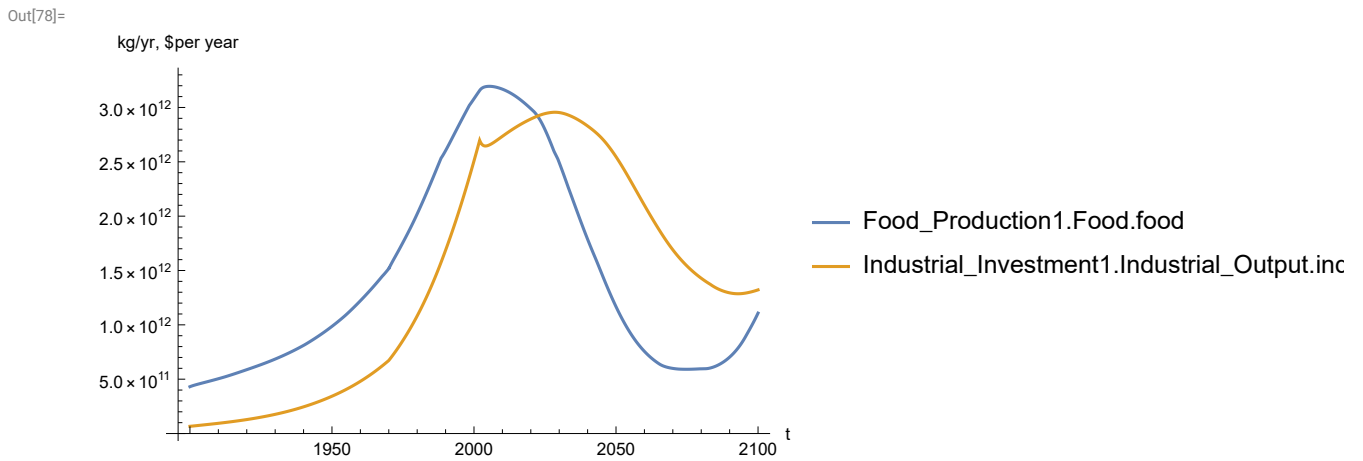
Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

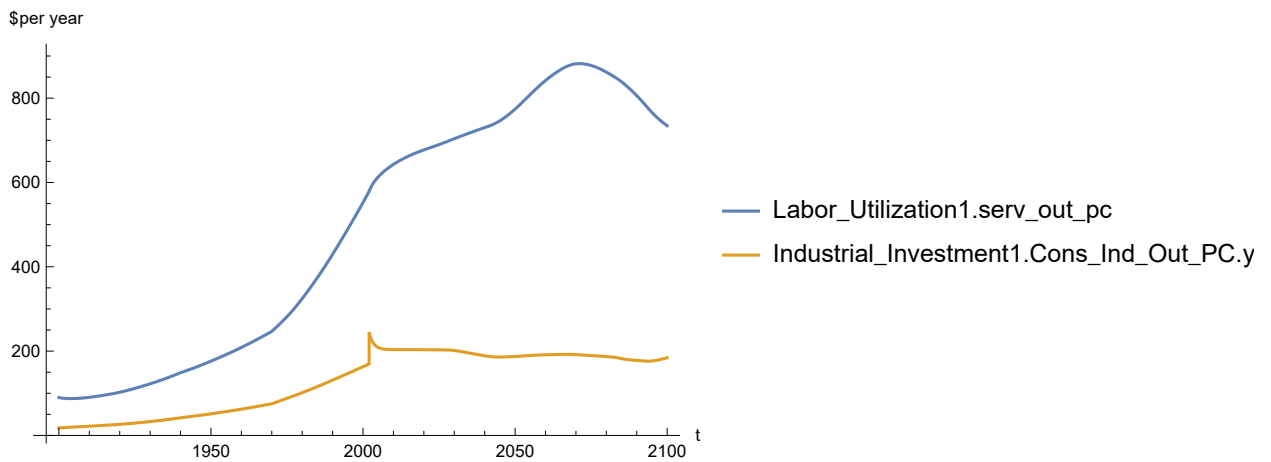
```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

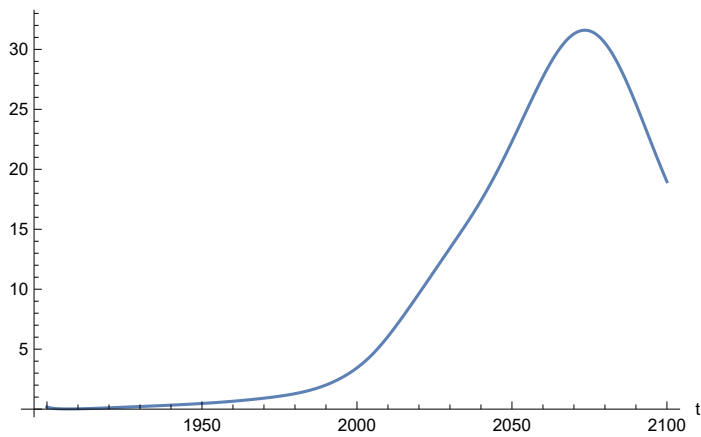
Maximum is 881.851

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

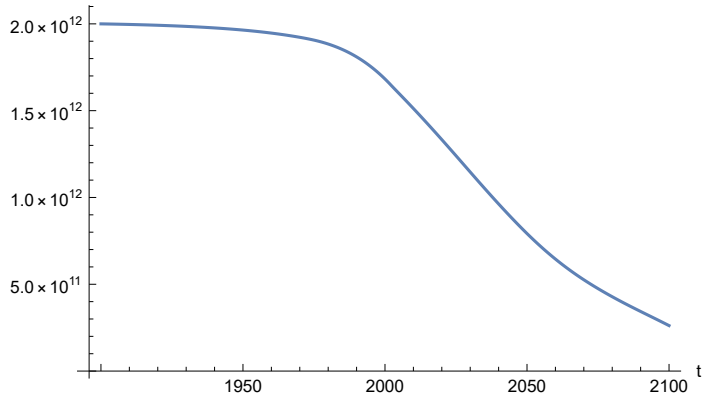
Maximum is 31.5982

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

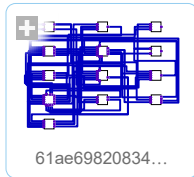
Out[83]=



APPENDIX 102. Baseline Scenario 8, Experiment 102. LE = LE/1.05, t_policity_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

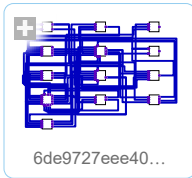
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



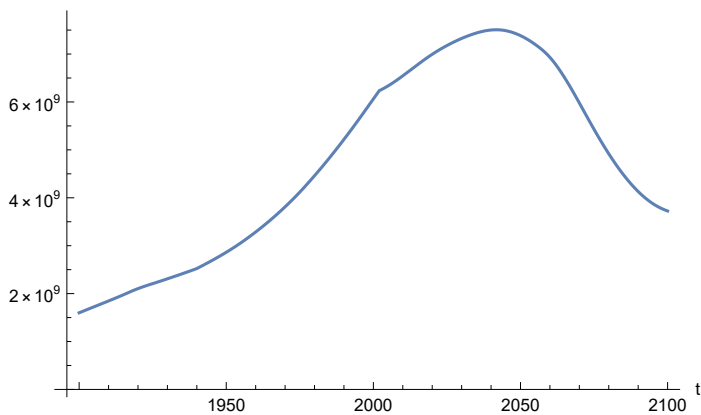
Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
Out[93]=
```

SystemModelSimulationData [ Model: W6de9727eee404651b7a379bfbf4d7111
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[94]=
```

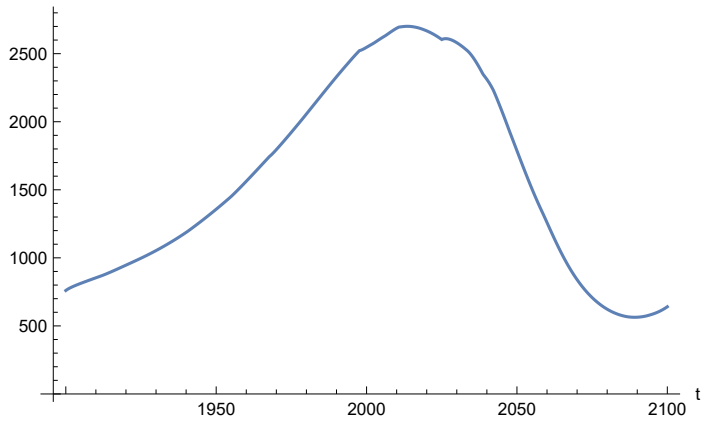


Find max and min of population values.

```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.50668 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

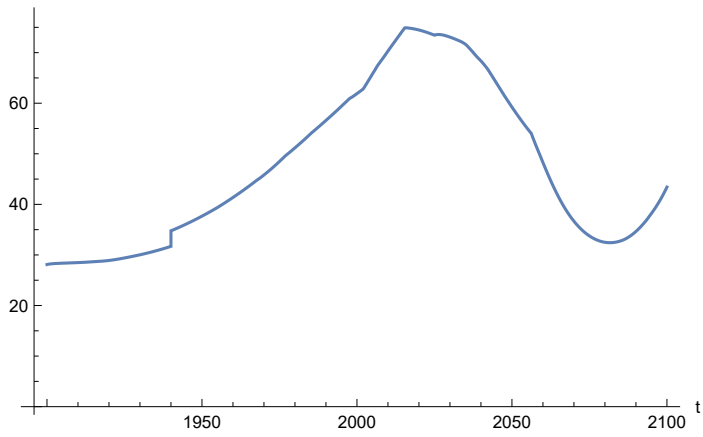
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

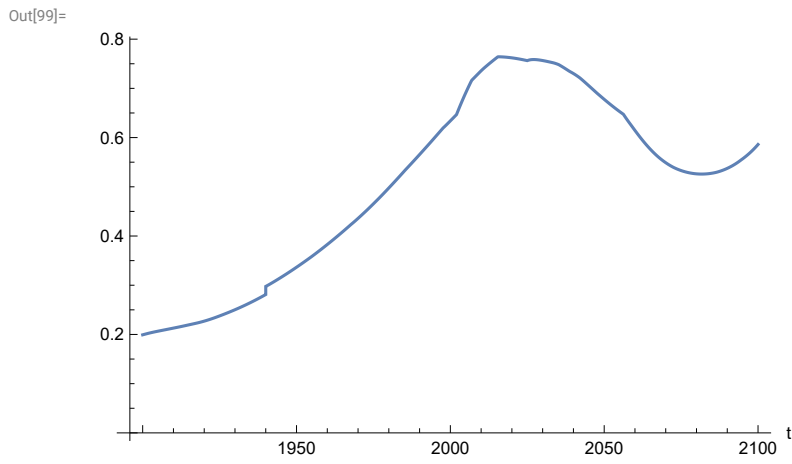
Out[97]=



In[98]:=

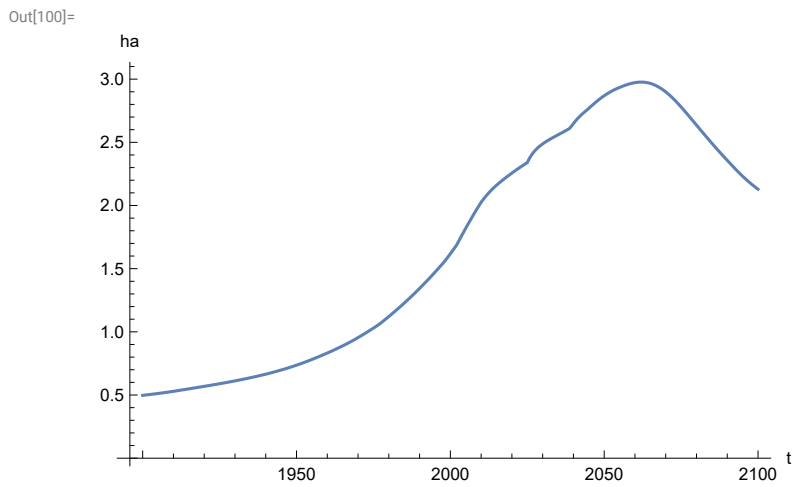
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

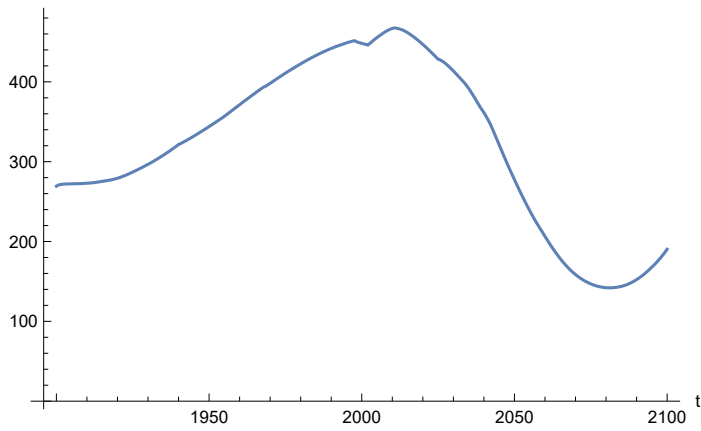


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

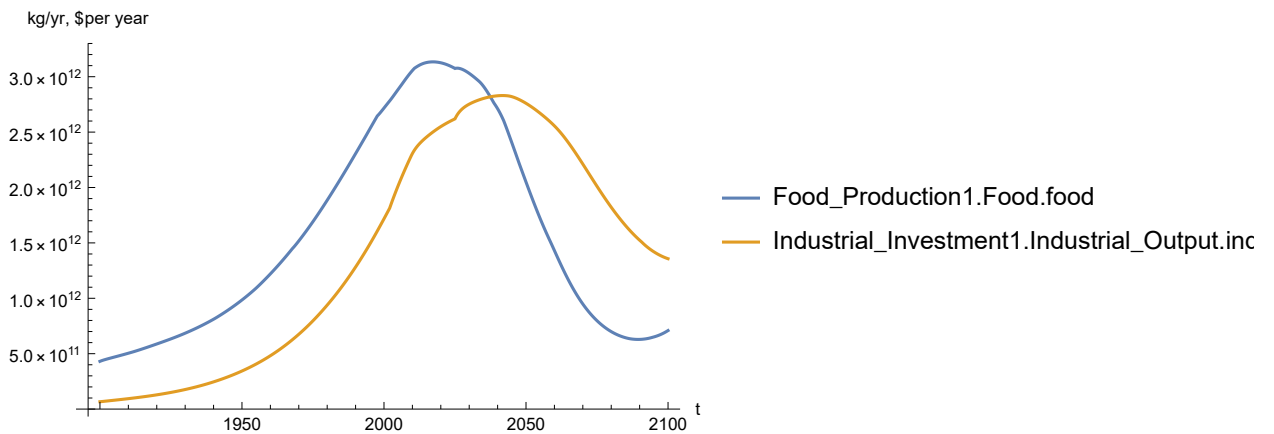


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

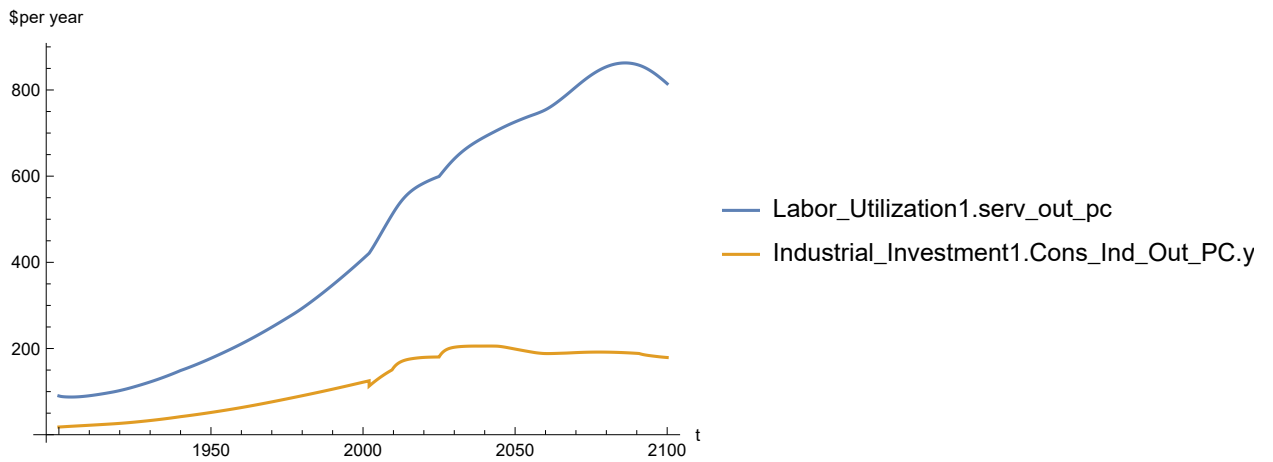


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

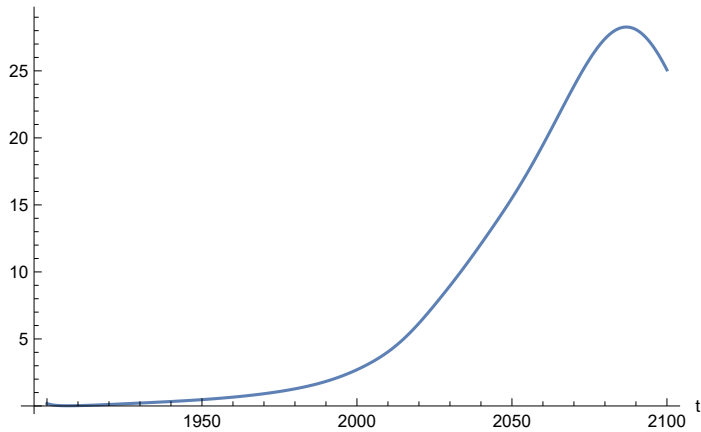
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 862.775
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 28.2686

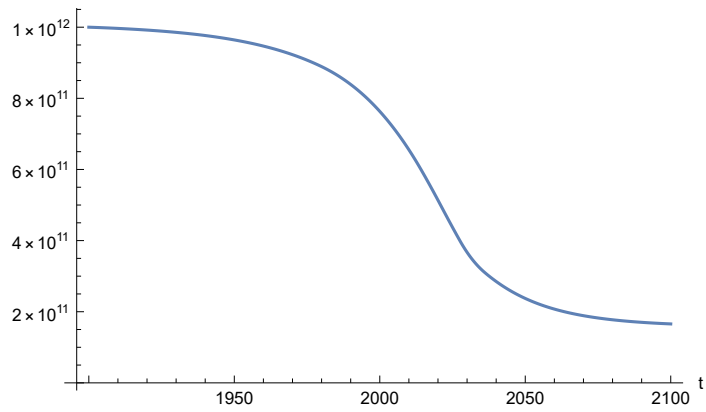
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[107]=



APPENDIX 103. BENCHMARK SCENARIO 8, Experiment 103. LE = LE/1.1, t_policy_year = 1970.

Last modified: 30 July 2022/1600 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

```
In[ ]:= RangeData[data_] := data[[1]][[4]][[3]];
```

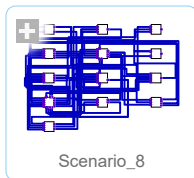
Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

```
In[ ]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
  Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 8.

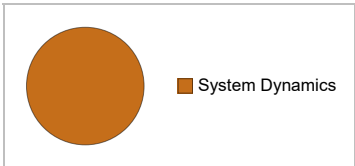
```
In[ ]:=  
mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_8"]
```

Out[]:=



```
In[*]:= mysummary = mysim["Summary"]
```

```
Out[*]=
```

M	SystemDynamics.WorldDynamics.World3.Scenario_8
D	More abundant non-recoverable natural resources, birth control, and stable industrial output
Sii	True
Pl	0
Cc	106
Bz	True
Sy	265
Sy	265
D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[*]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

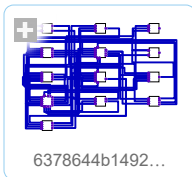
```
Out[*]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[ ]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[ ]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[ ]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
Out[ ]:=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

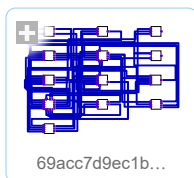
```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

```
In[ ]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

```
Out[ ]:=
```



Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim1970]
```

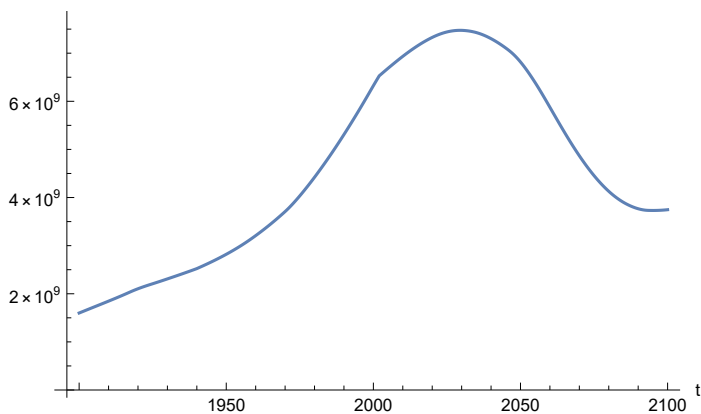
```
Out[ ]:=
```

```
SystemModelSimulationData [ Model: W69acc7d9ec1b4404a4db7da6727e3dbf
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

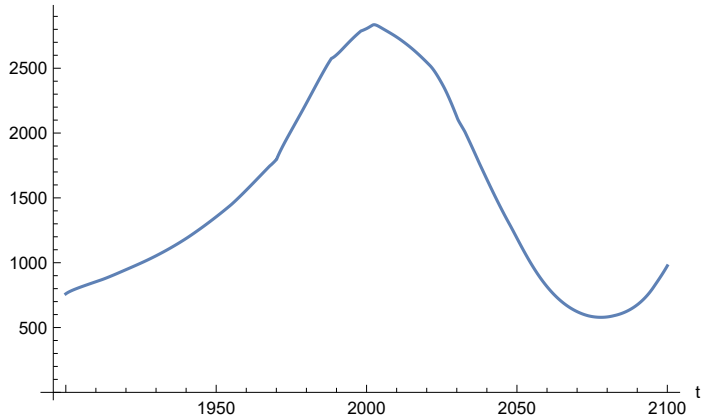
```
Out[ ]:=
```



Find max and min of population values.

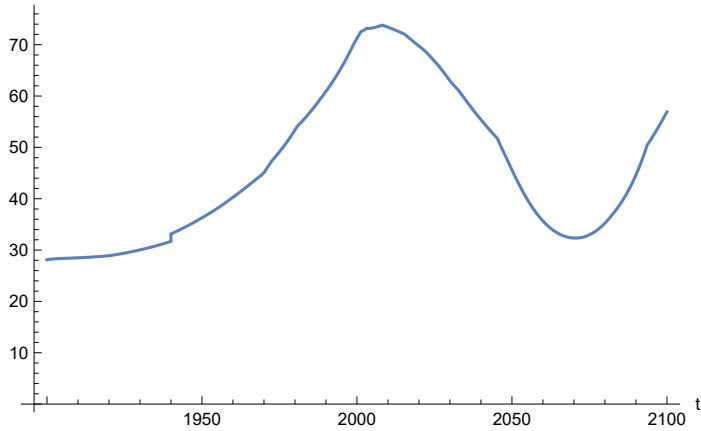
```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.47503 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[ ]:=
```



Plot life expectancy, years.

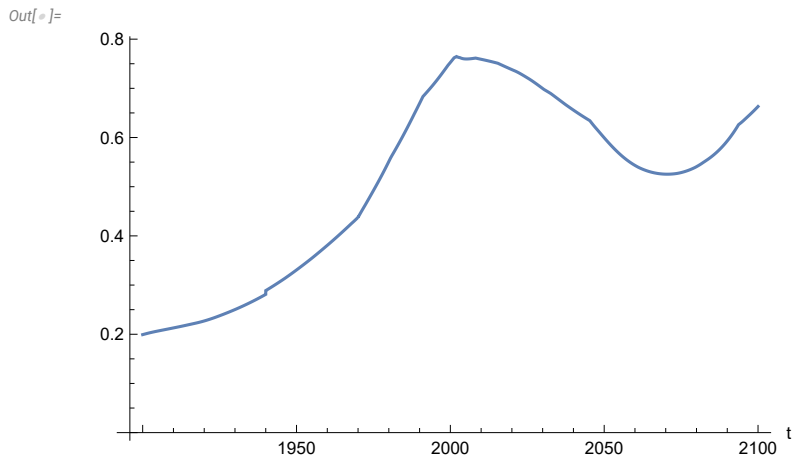
```
In[ ]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[ ]:=
```



```
In[ ]:=
```

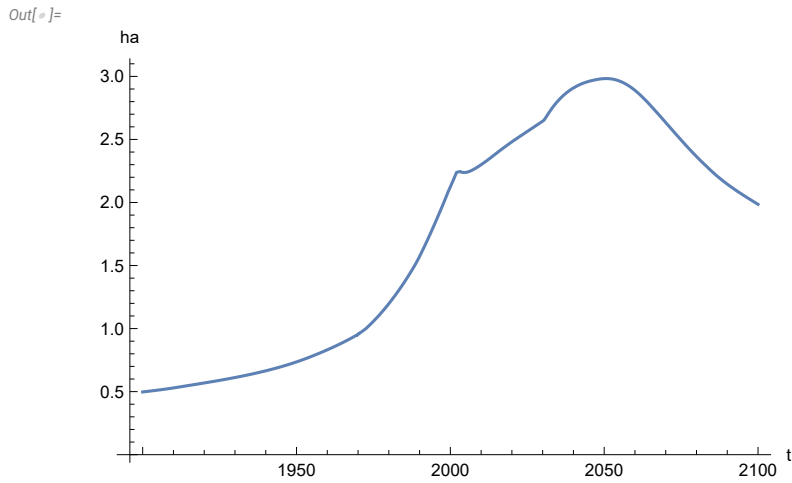
Plot human welfare index.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

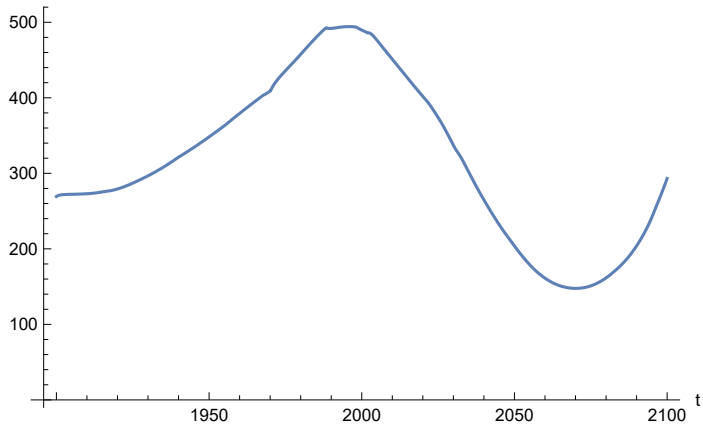
```
In[*]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

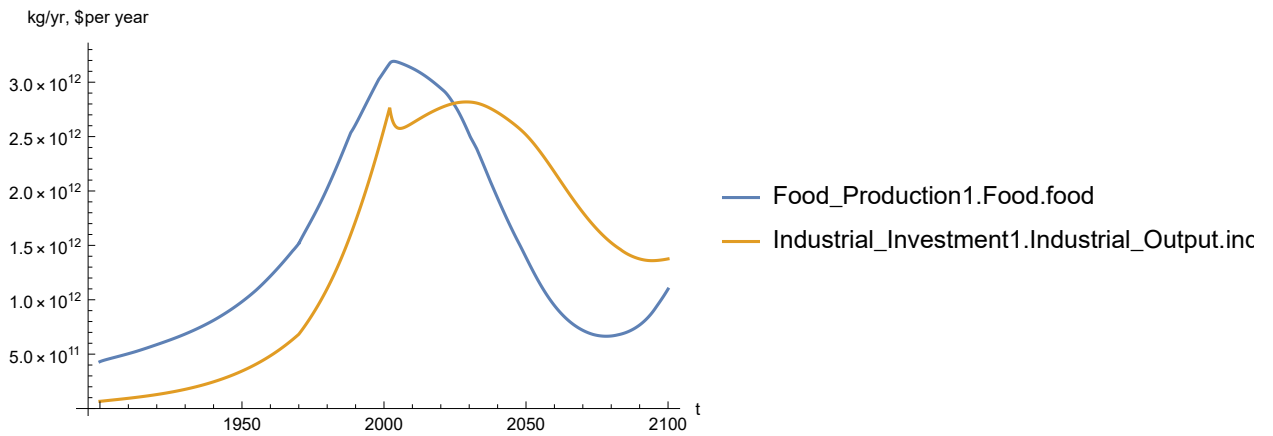
Out[]:=



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

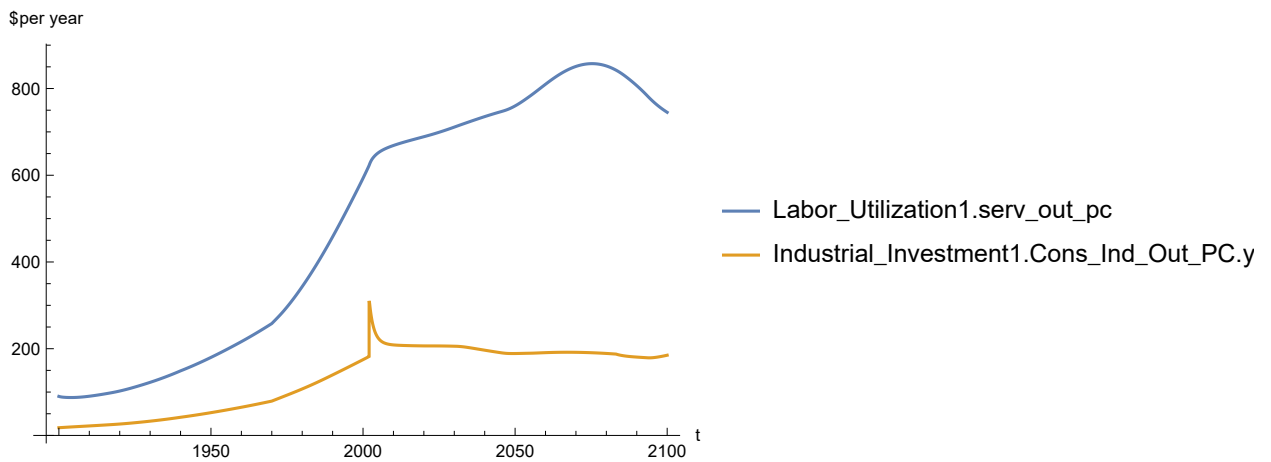
Out[]:=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[ ]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[]:=



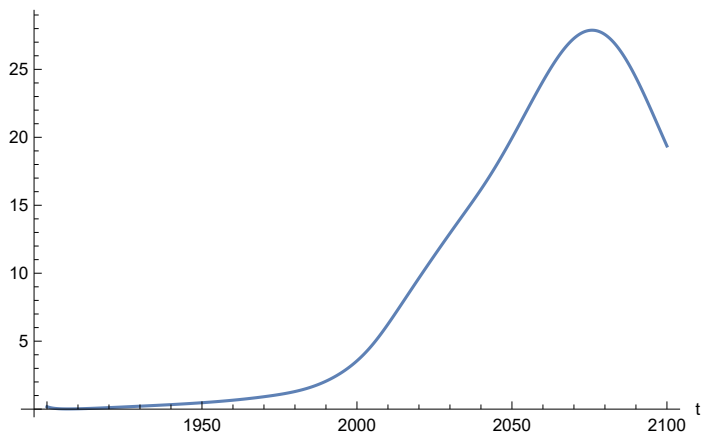
Find max and min of y values.

```
In[ ]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 857.366
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[ ]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[]:=

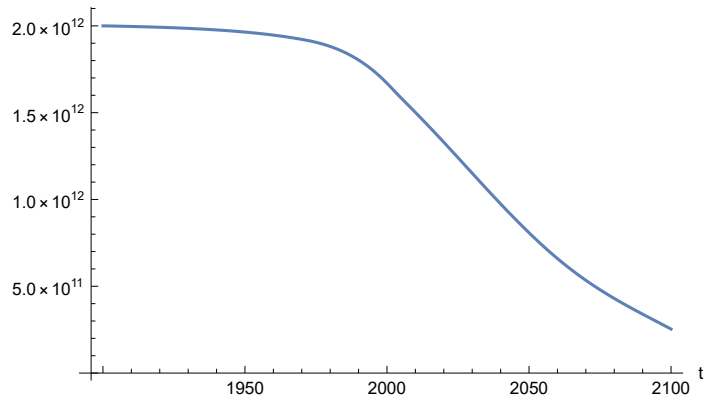


Find max and min of y values.

```
In[ ]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 27.8803
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[*]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[*]=
```

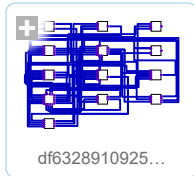


APPENDIX 104. LE/1.1, t_policy_year = 2025. Baseline Scenario 8, Experiment 103.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[ ]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}}|>]
```

Out[]:=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

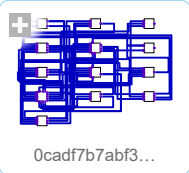
```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set t_policy_year to 2025.

```
In[ ]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
```

```
Out[ ]:=
```




0cadf7b7abf3...

Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim2025]
```

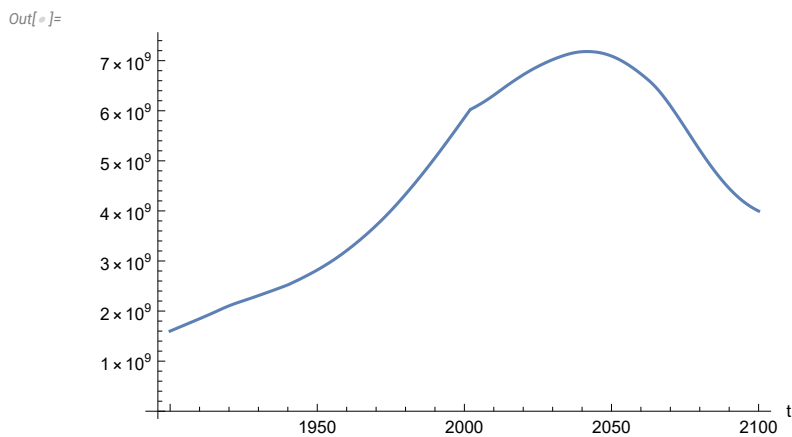
```
Out[ ]:= SystemModelSimulationData [
```



```
Model: W0cadf7b7abf3447b982528105ebc0e65
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

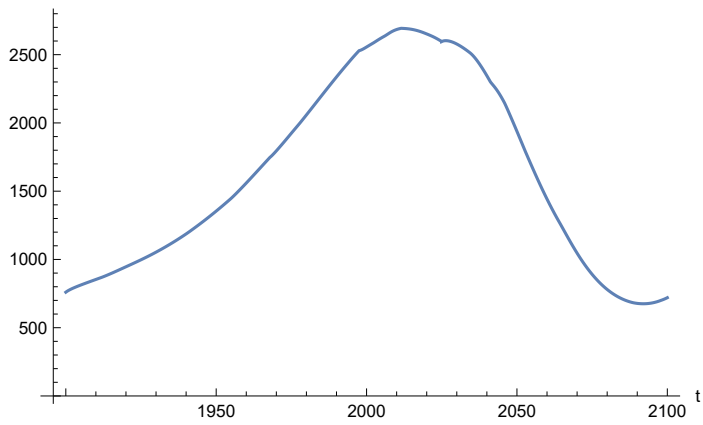
```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.18252×10^9

Minimum is 1.6×10^9

```
In[*]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

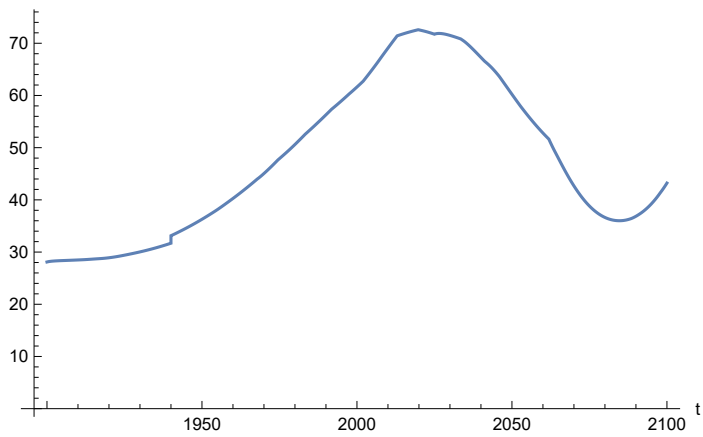
Out[*]=



Plot life expectancy, years.

```
In[*]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

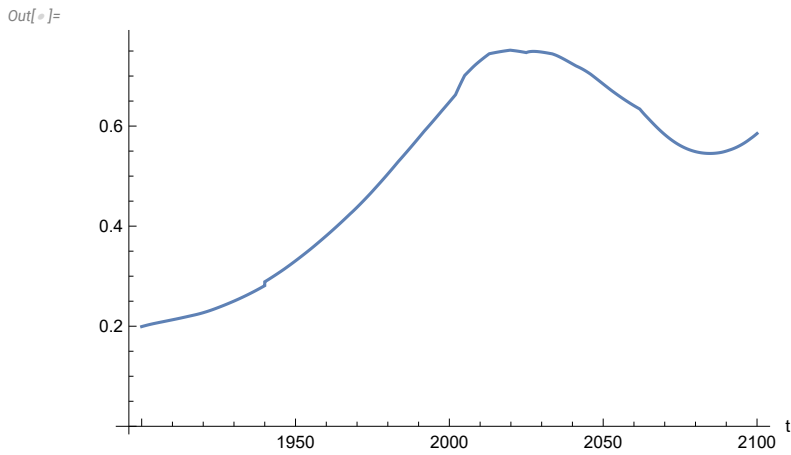
Out[*]=



In[*]=

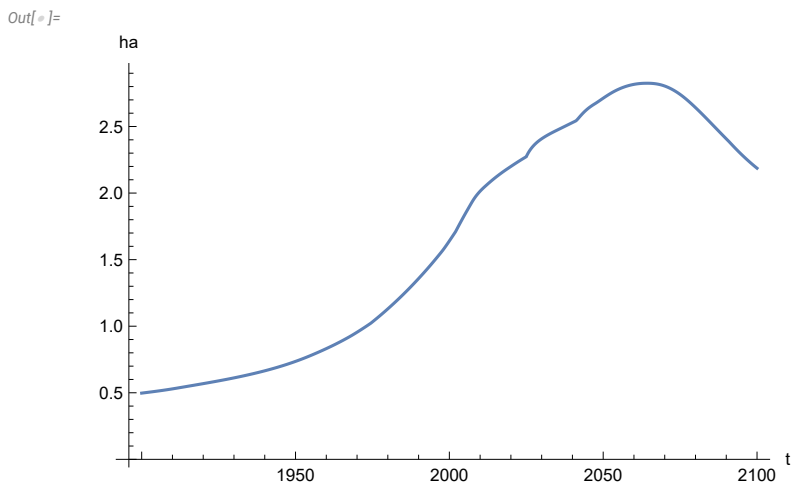
Plot human welfare index.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HEF_Human_Welfare_Index.hwi_human_welfare_index"}]
```



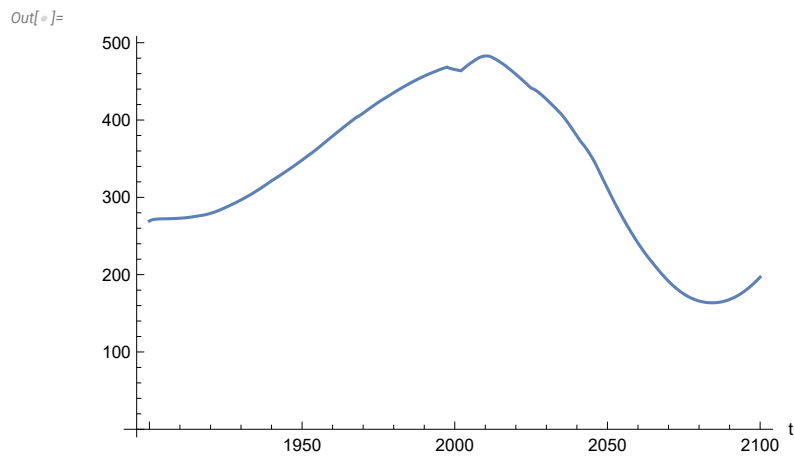
Plot per capita ecological footprint, hectares.

```
In[*]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



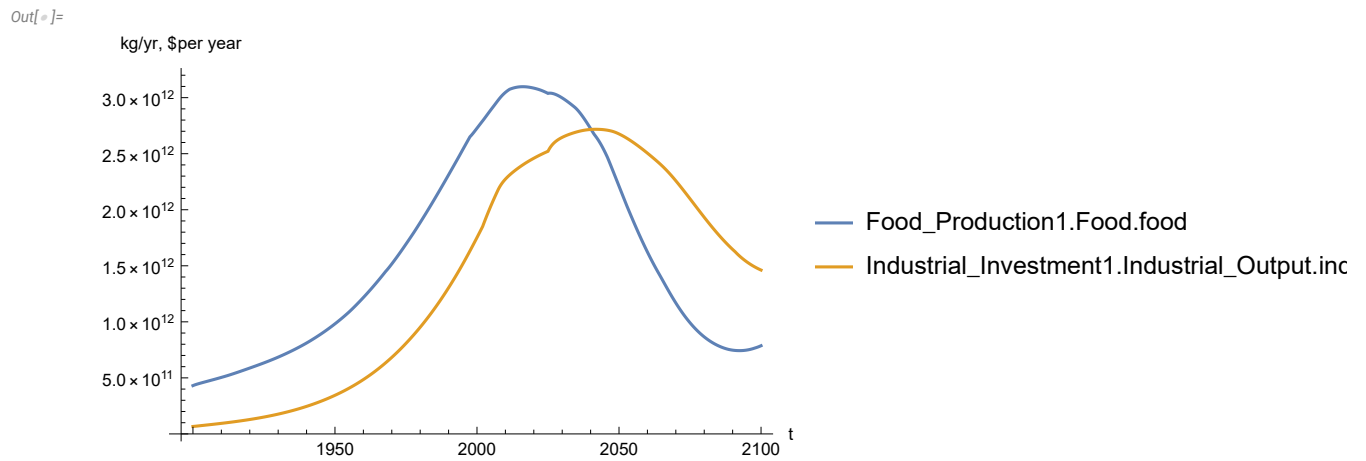
Plot food production per capita (kg/year).

In[*]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]



Plot total food production (kg/year), and industrial output (dollars/year).

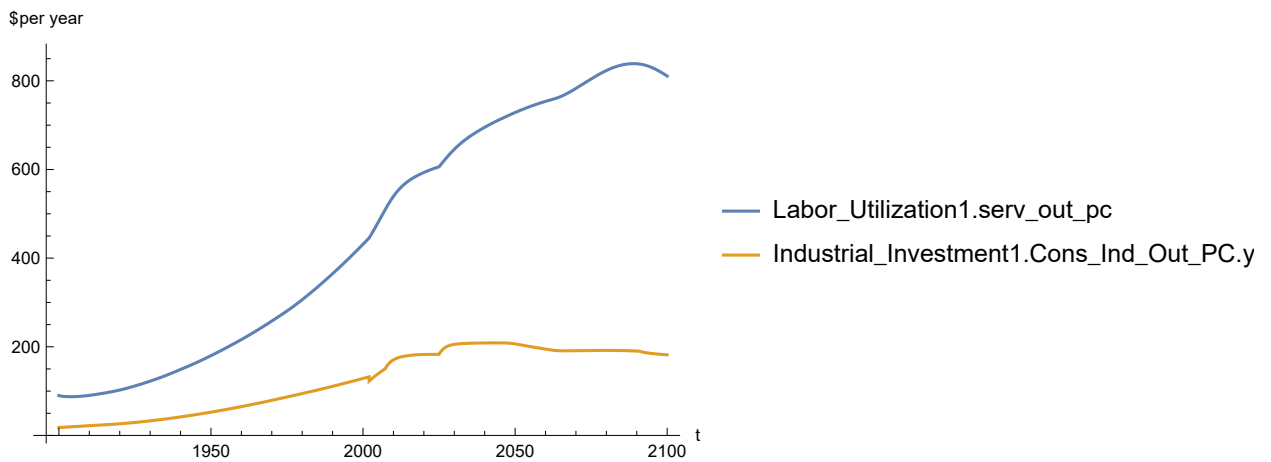
In[*]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[ ]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[]:=



Find max and min of y values.

```
In[ ]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

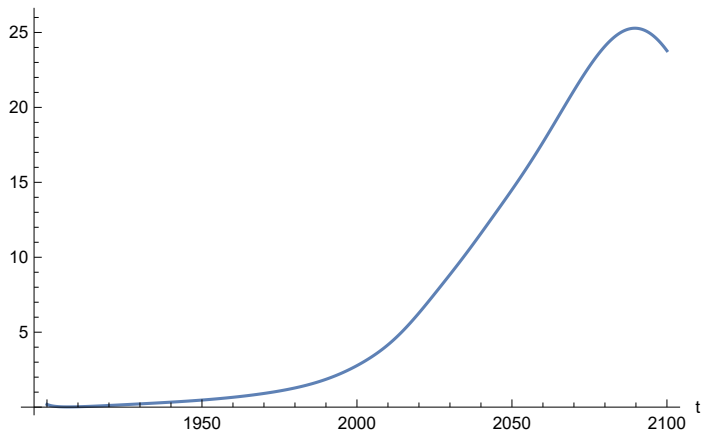
Maximum is 838.777

Minimum is 87.4451

Plot persistent pollution index.

```
In[ ]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[]:=



Find max and min of y values.

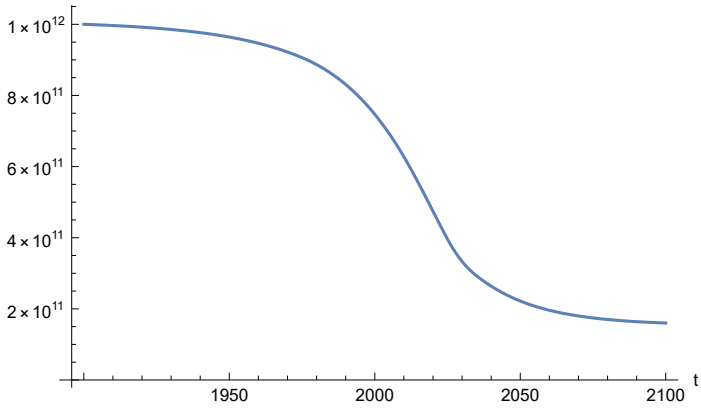
```
In[ ]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 25.2835

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[*]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[*]=
```



APPENDIX 8A1. BENCHMARK SCENARIO 8, Experiment 8A1. $LE = LE/1.001$, $t_{policy_year} = 2002$.

Last modified: 31 July 2022/1210 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

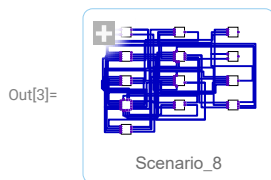
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

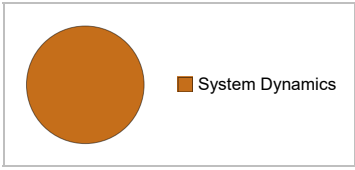
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 8.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_8"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_8
	D	More abundant non-recoverable natural resources, birth control, and stable industrial output
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

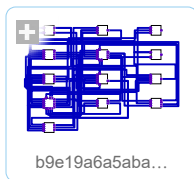
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

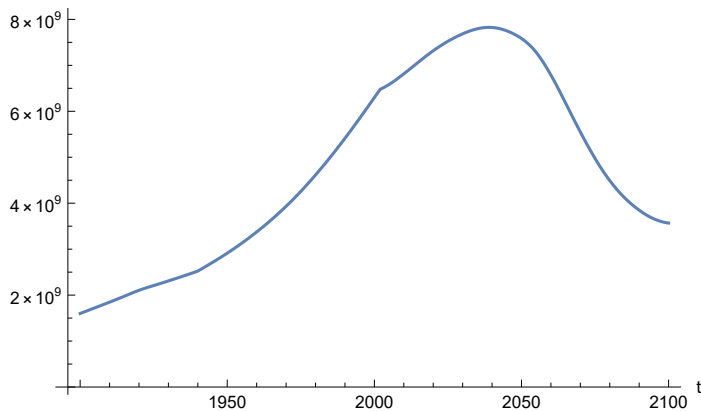
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Wb9e19a6a5aba47e6b18224208c2c7482  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

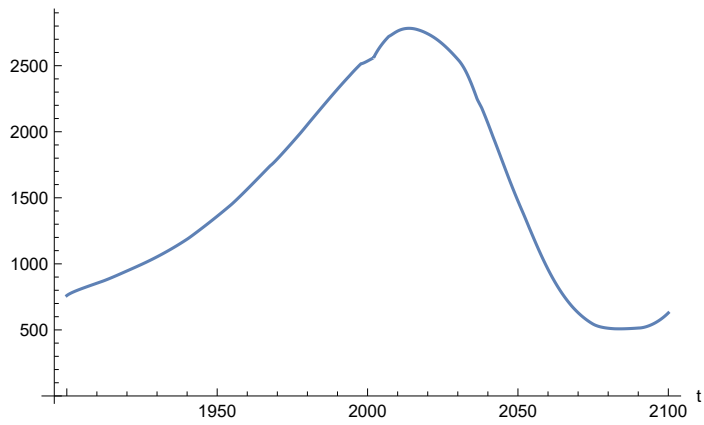
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.82639 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

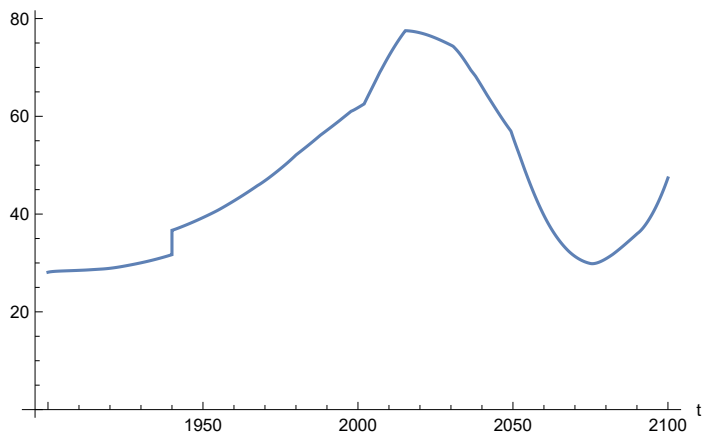
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

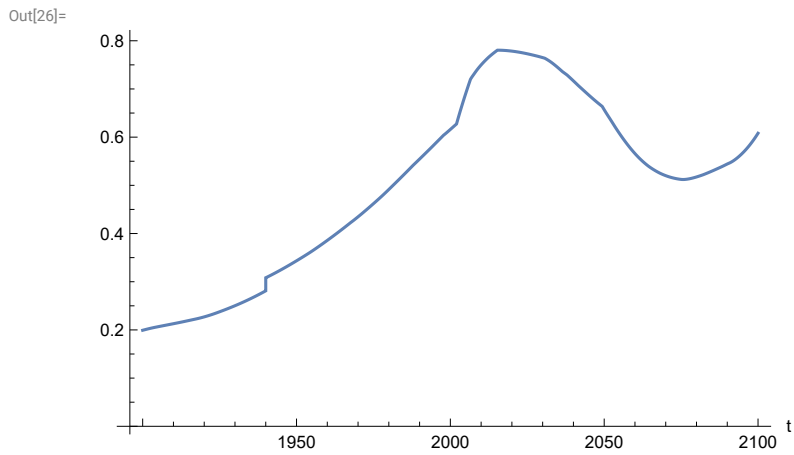
Out[24]=



In[25]:=

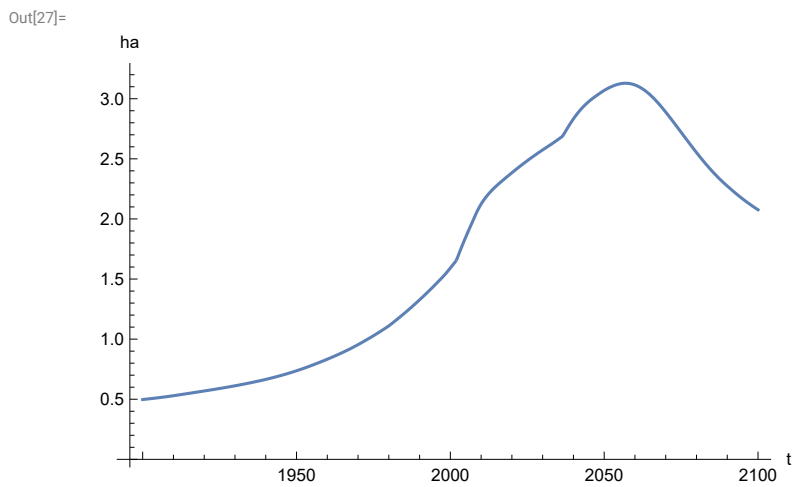
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

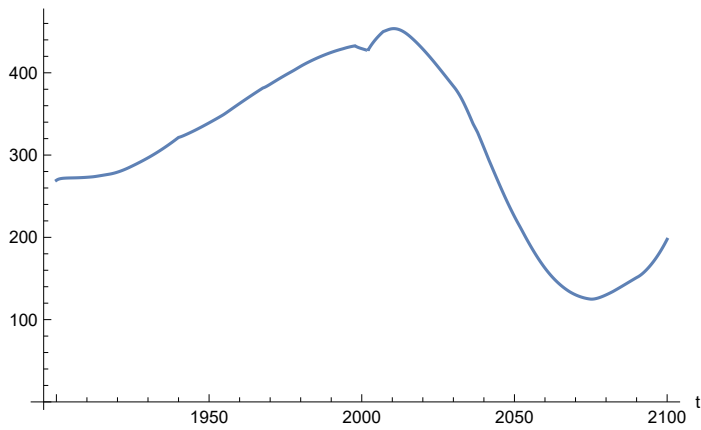
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

```
In[28]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

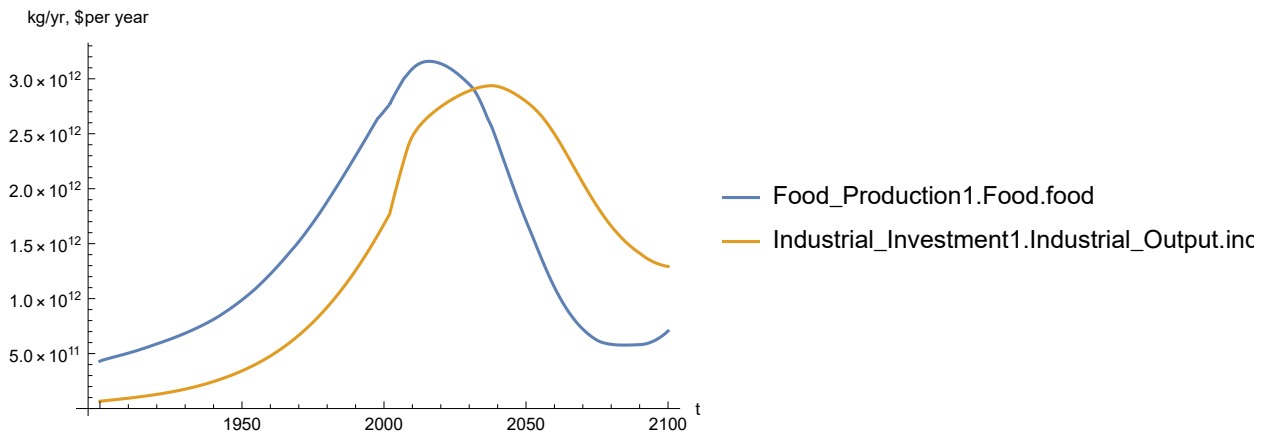
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

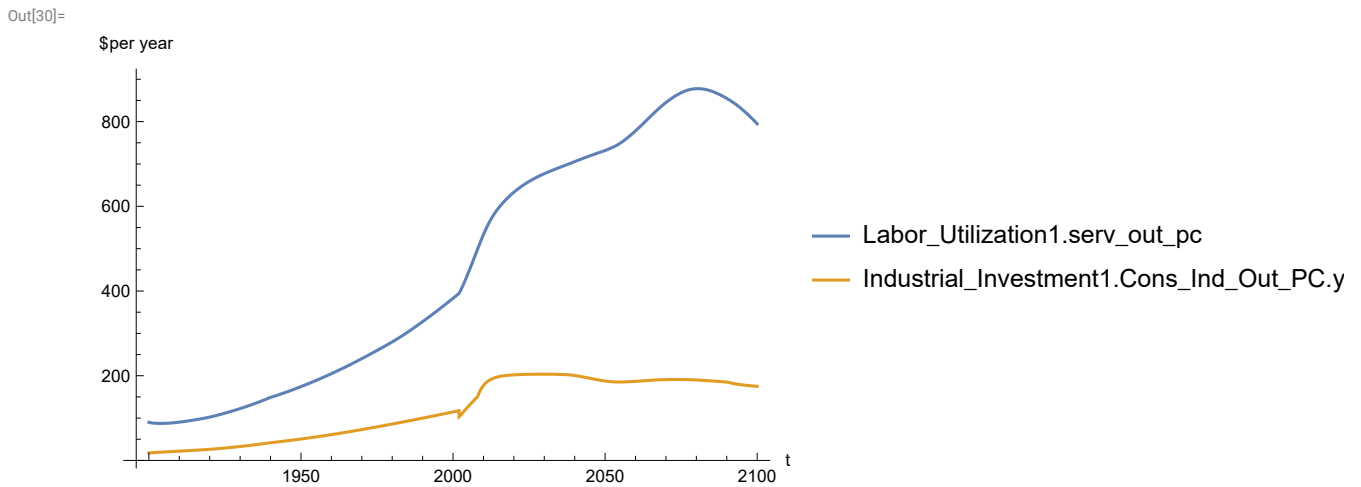
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

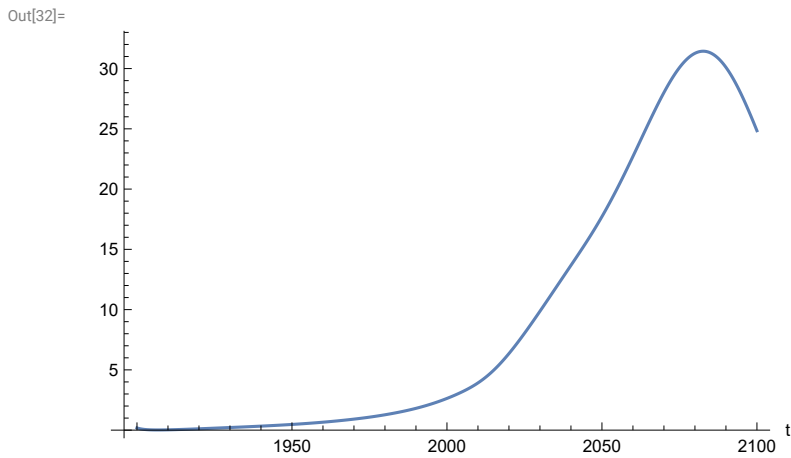


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 877.873
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



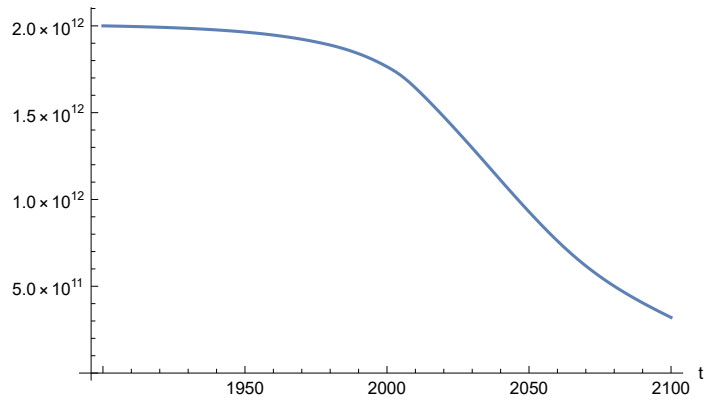
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 31.4397
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

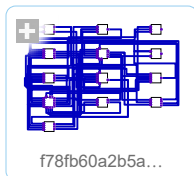


APPENDIX 8A2. LE/1.01, t_policy_year =2002. Baseline Scenario 8A2, Experiment 8A2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=


```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

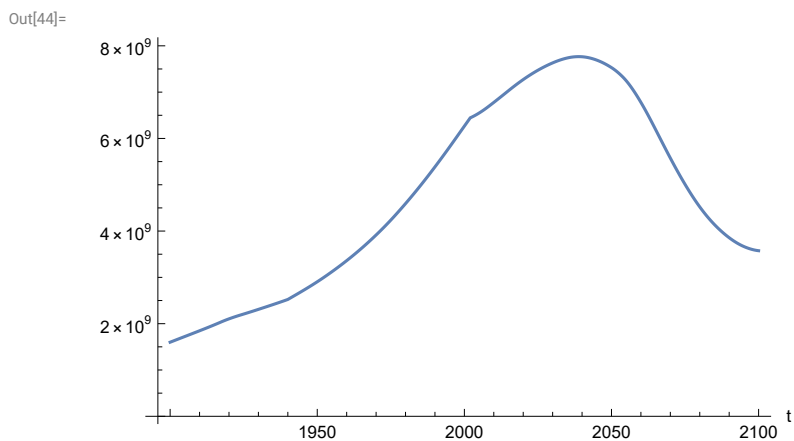
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: Wf78fb60a2b5a4886baca6de2c41d4330
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

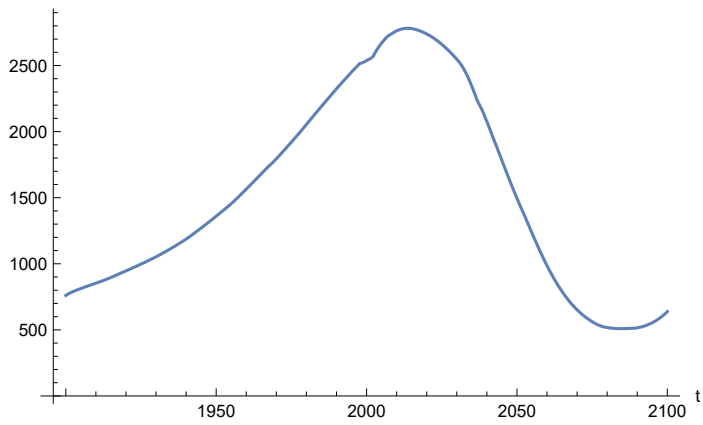
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.76657 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

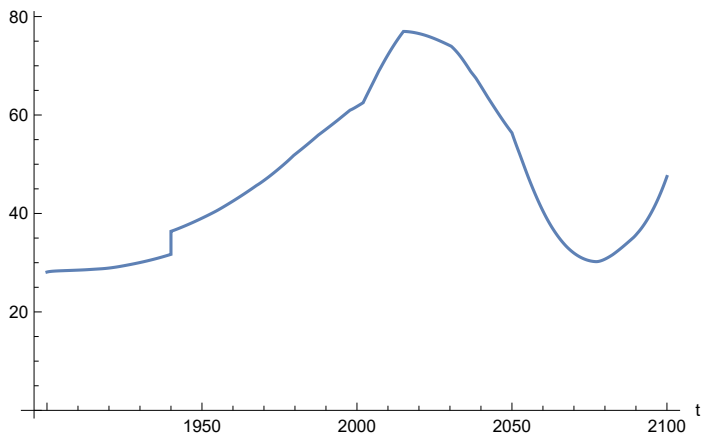
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

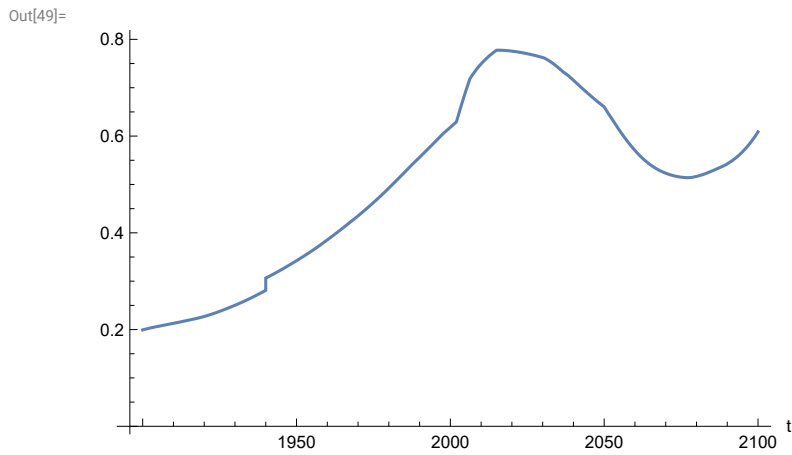
Out[47]=



In[48]=

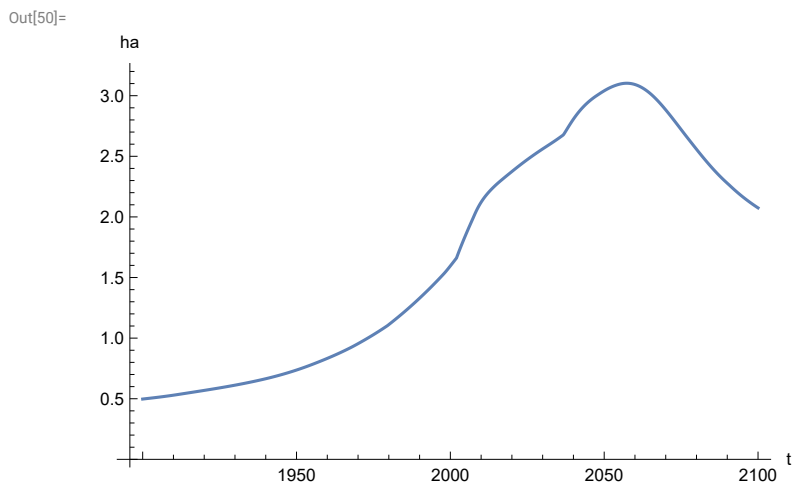
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

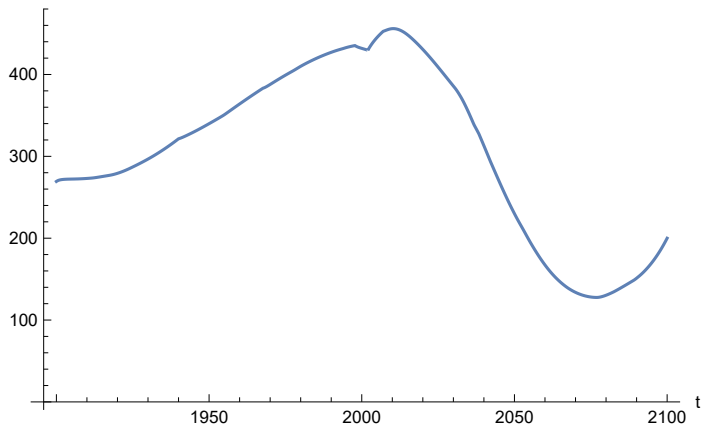
```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

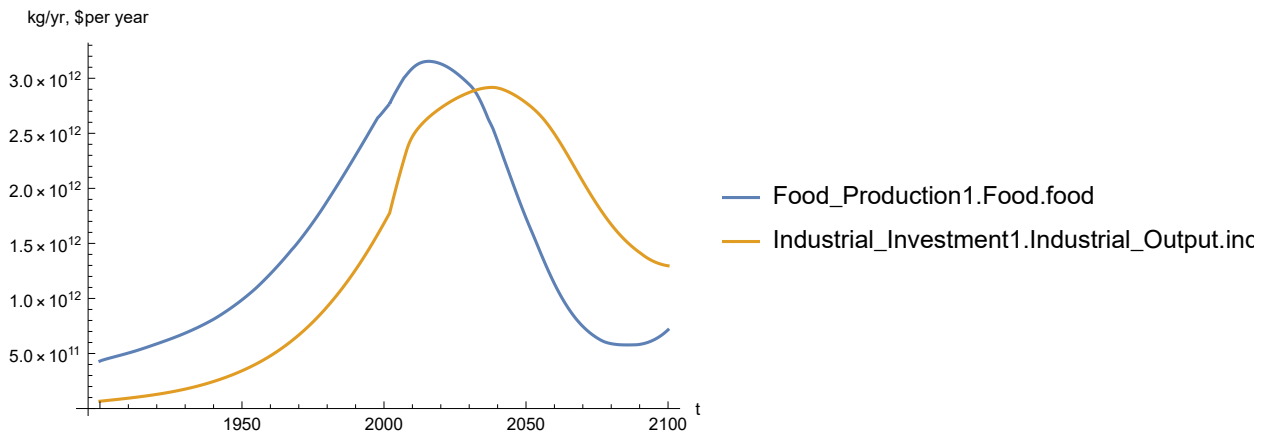
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

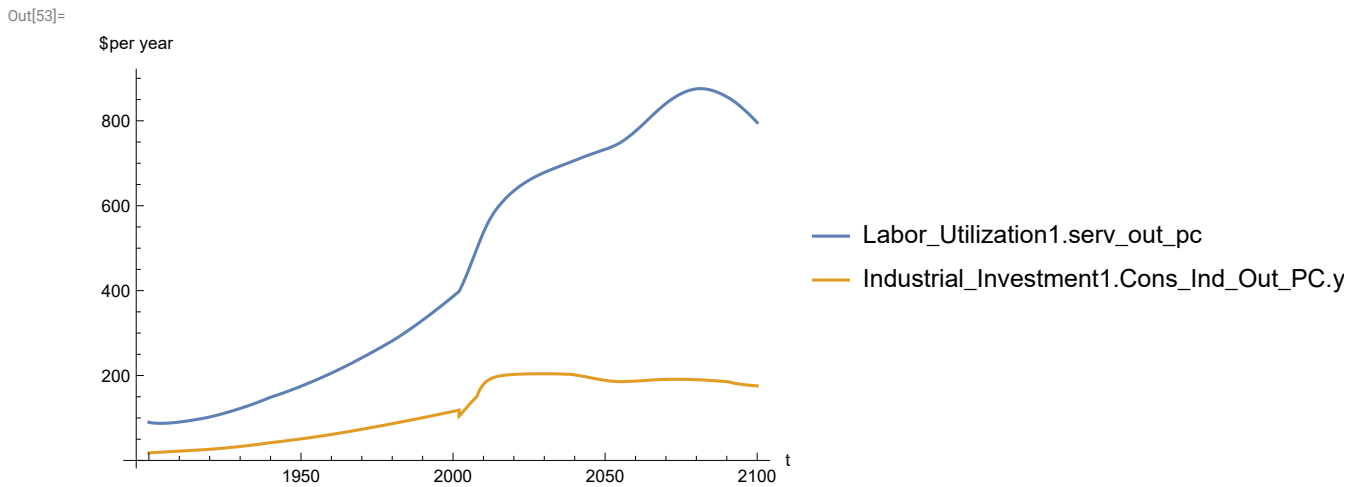
In[52]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

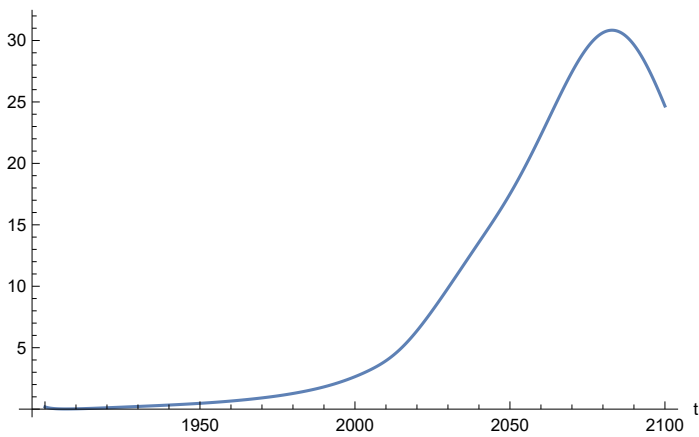


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 875.764
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



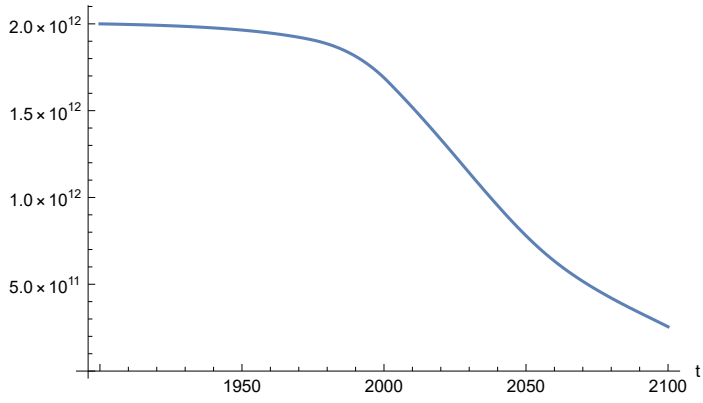
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 30.8374
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 8B1. BENCHMARK SCENARIO 8, Experiment 8B1. $LE = LE/1.03$, $t_policy_year = 2002$.

Last modified: 27 July 2022/1430 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

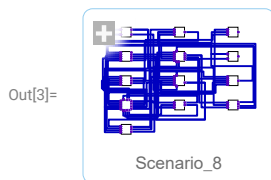
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

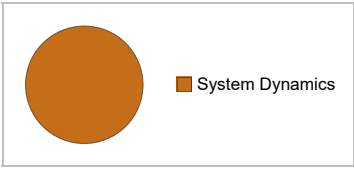
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 8.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_8"]
```



In[4]:= **mysummary = mysim["Summary"]**

	Model	SystemDynamics.WorldDynamics.World3.Scenario_8
	Description	More abundant non-recoverable natural resources, birth control, and stable industrial output
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	Summary	265
	Summary	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

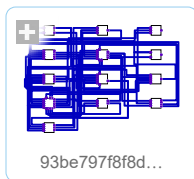
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

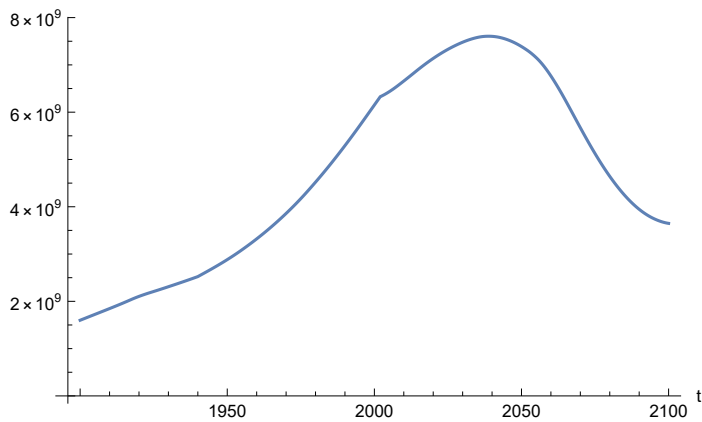
```
Out[20]=
```

```
SystemModelSimulationData [  Model: W93be797f8f8d41bba9473f6879d3cf69  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

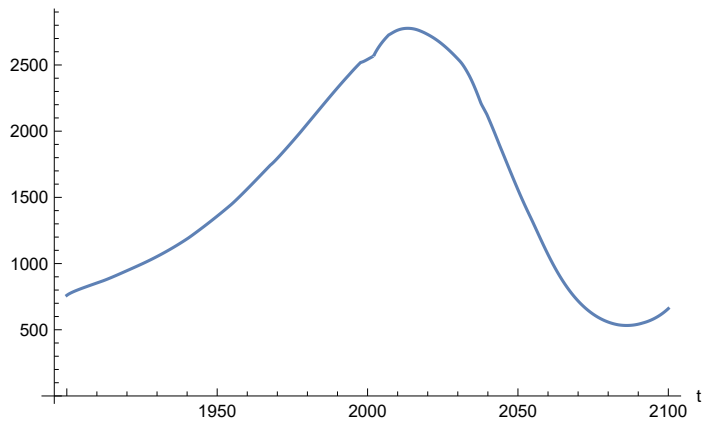
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.60597 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

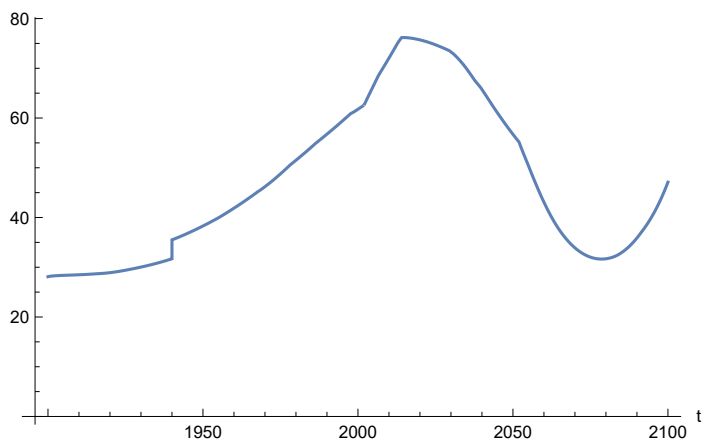
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

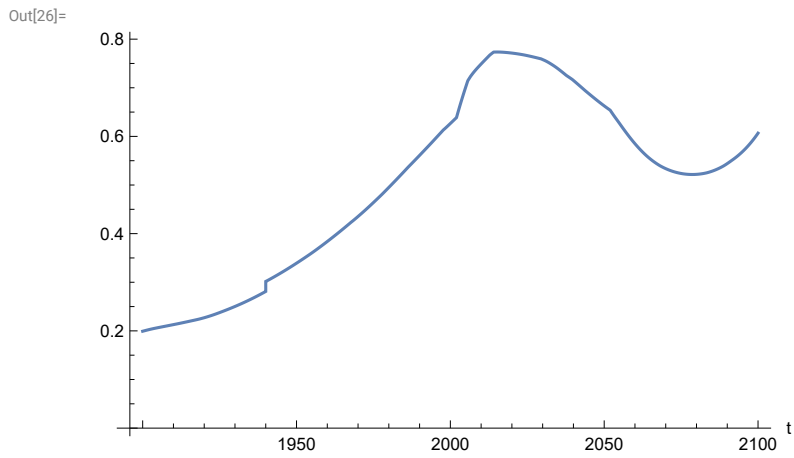
Out[24]=



In[25]=

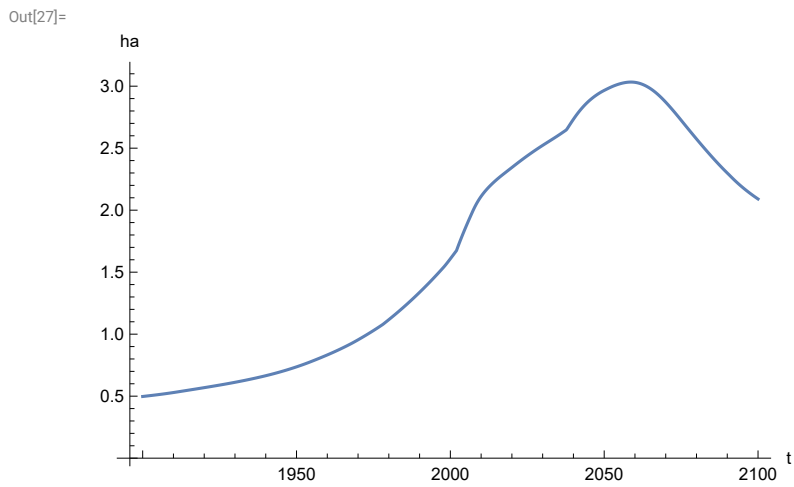
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

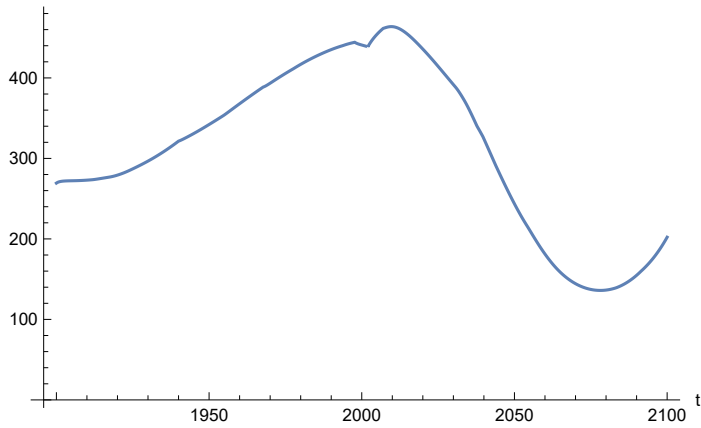
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

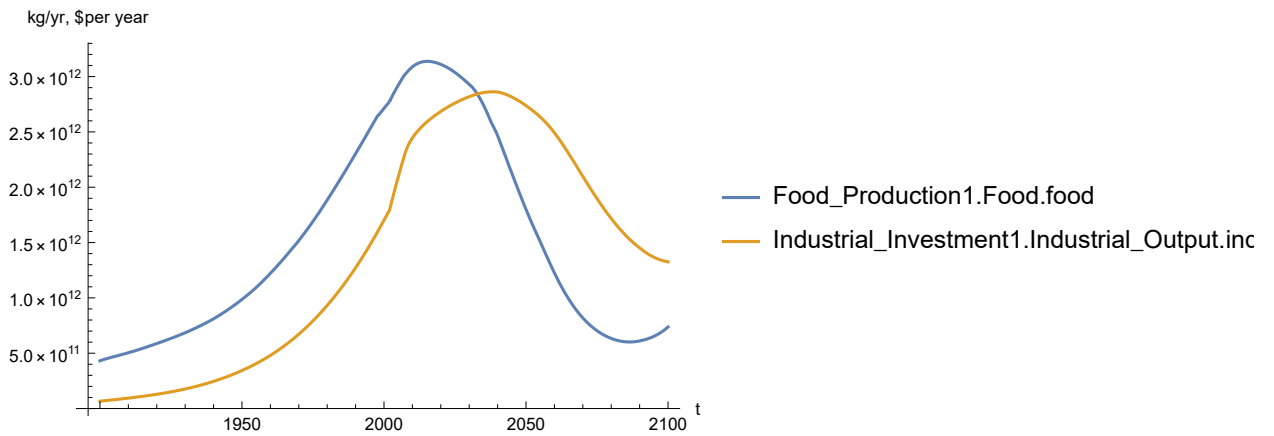
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

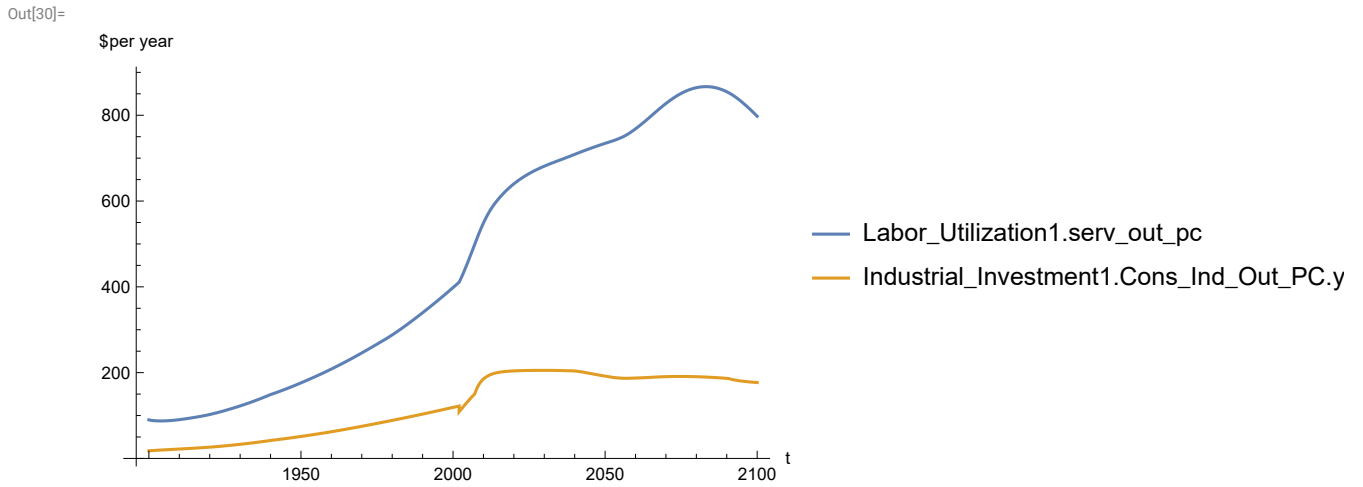
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

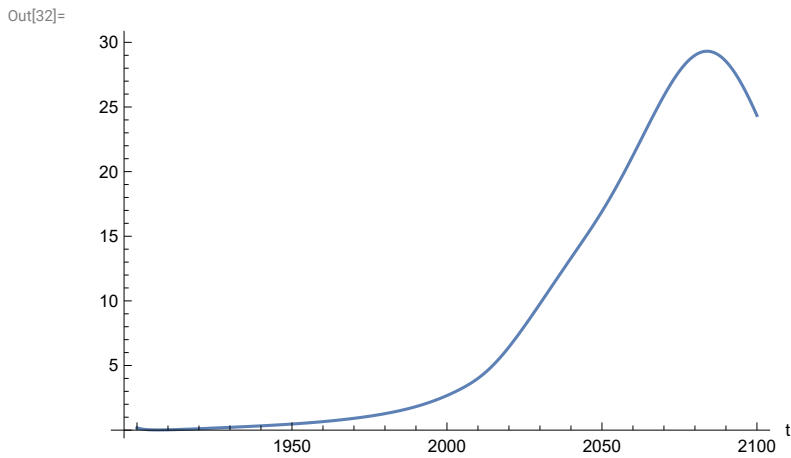


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 866.704
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



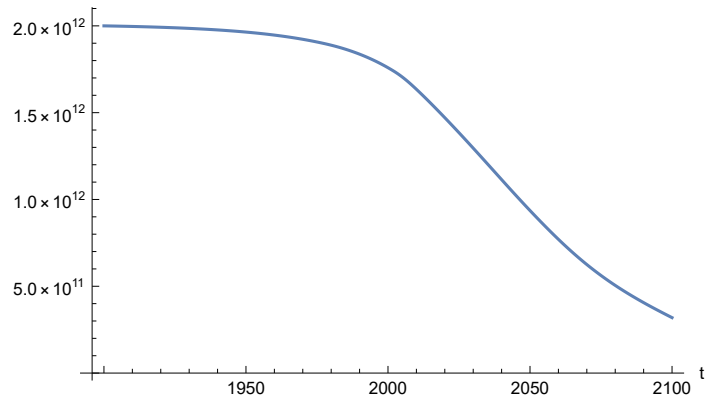
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 29.3154
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

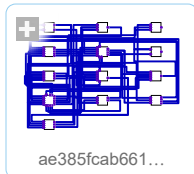


APPENDIX 8B2. LE/1.05, t_policy_year = 2002. Baseline Scenario 8, Experiment 8B2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

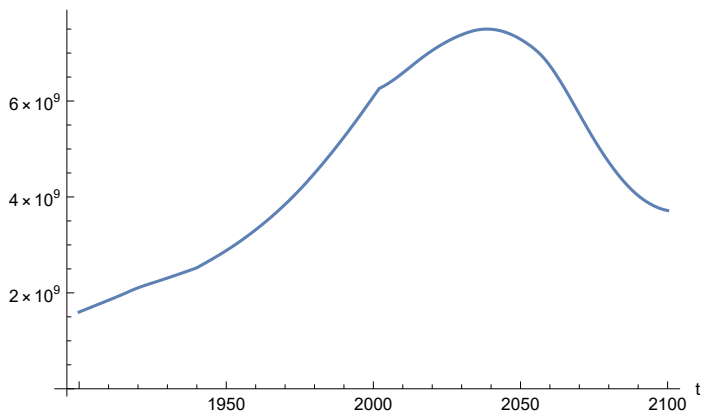
```
Out[43]=
```

```
SystemModelSimulationData [  Model: Wae385fcab6614436b40a307e46f176f8
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[44]=
```



Find max and min of population values.

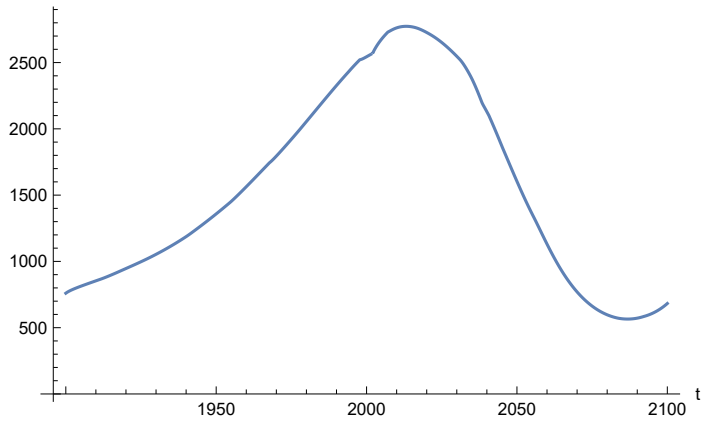
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.49952 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

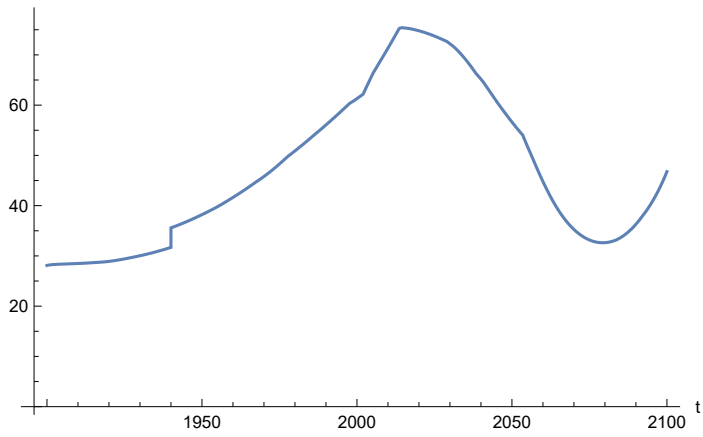
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

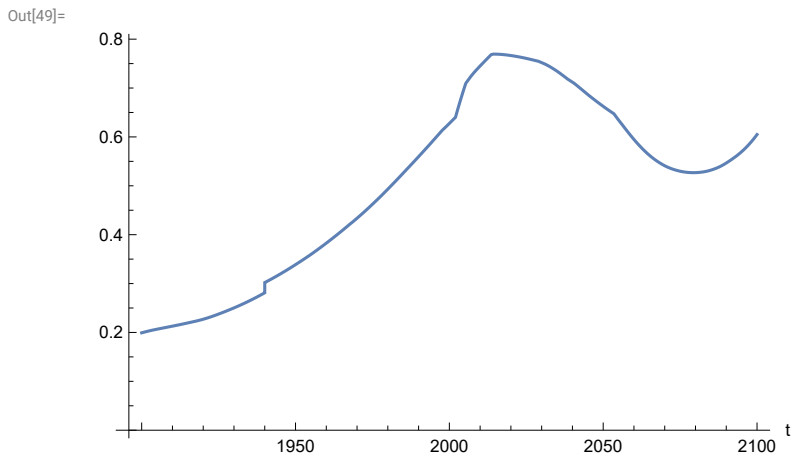
Out[47]=



In[48]:=

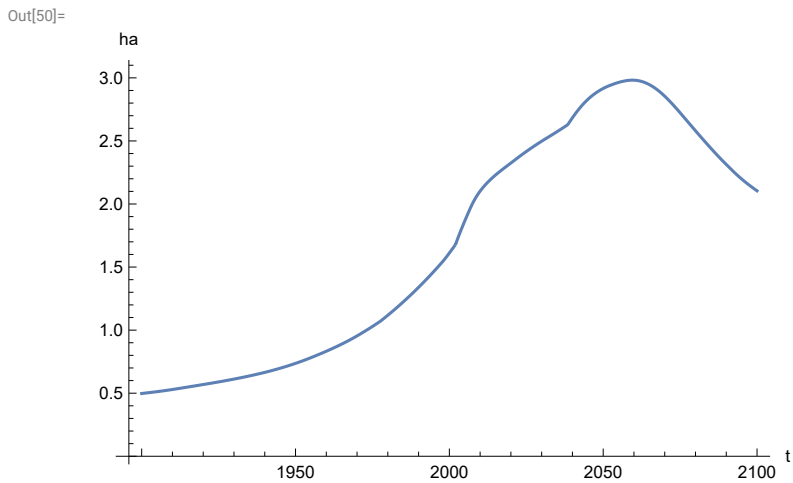
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

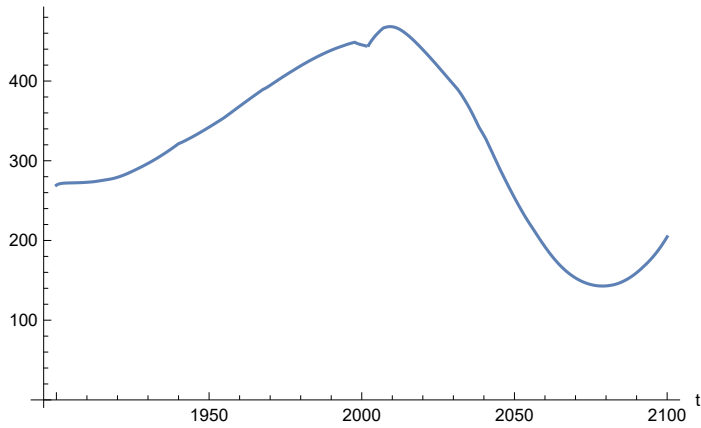
```
In[50]:= SystemModelPlot[basesim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

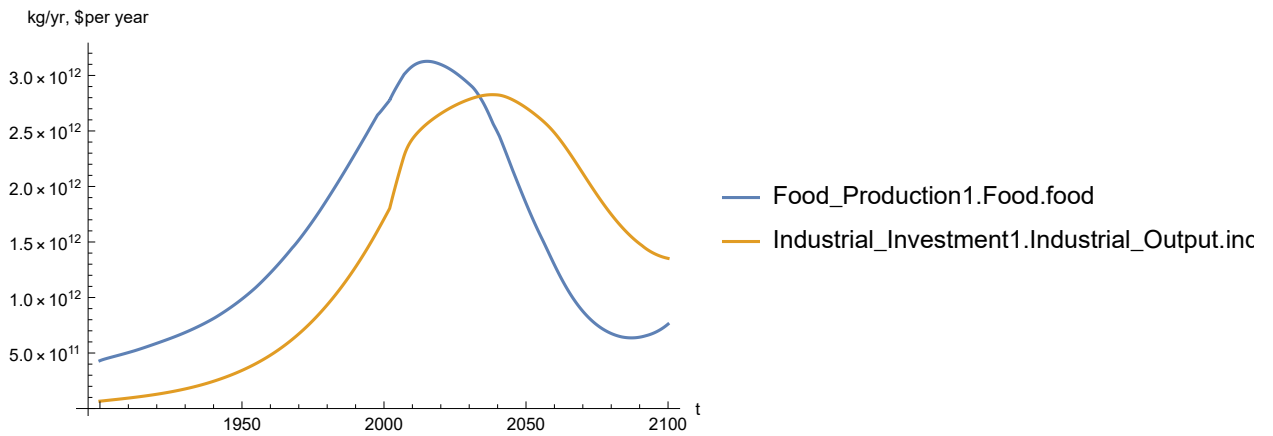
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

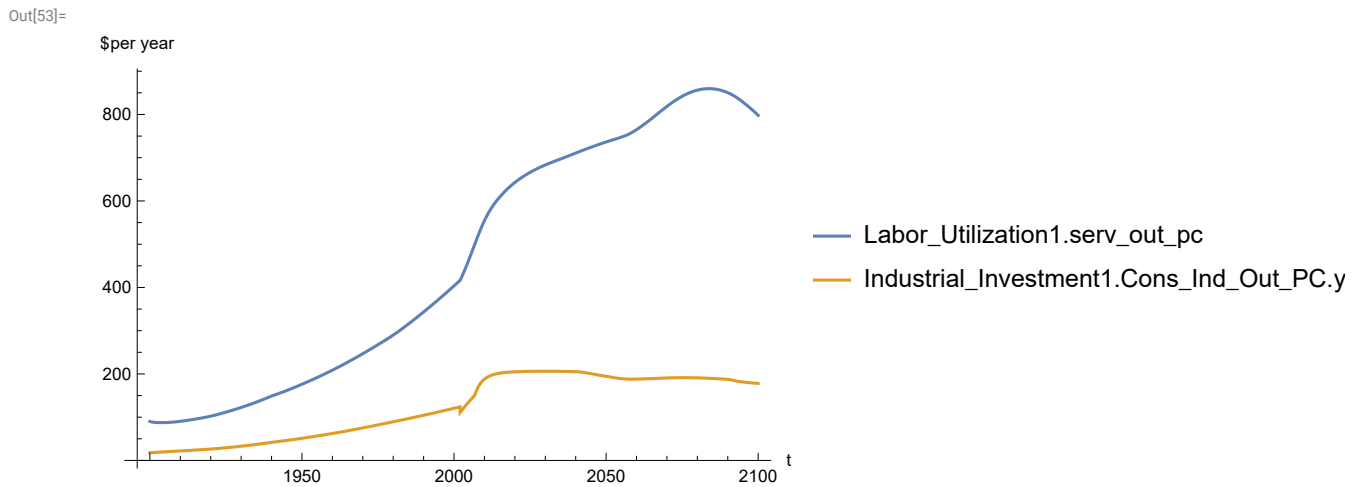
In[52]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

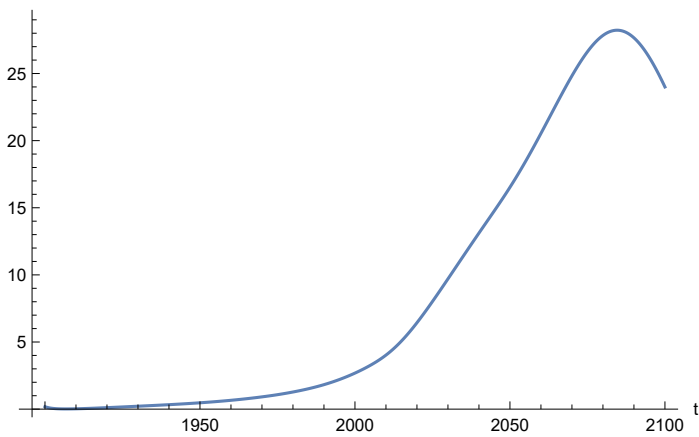


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 859.715
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



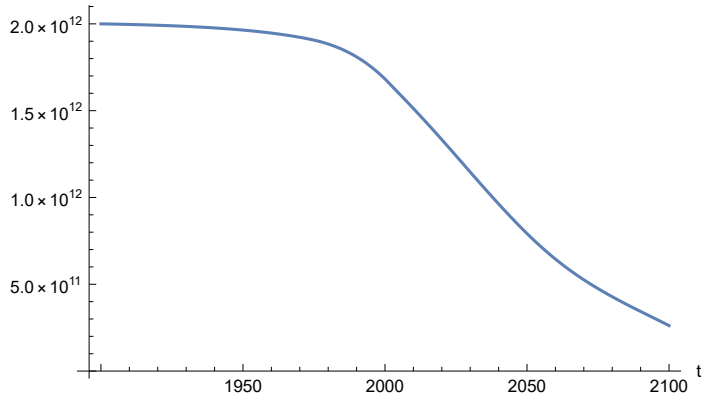
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 28.2254
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 8C1. BENCHMARK SCENARIO 8, Experiment 8C1. $LE = LE/1.1$, $t_policy_year = 2002$.

Last modified: 30 July 2022/1230 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

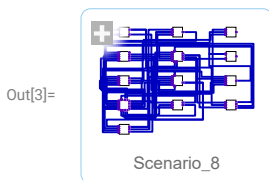
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

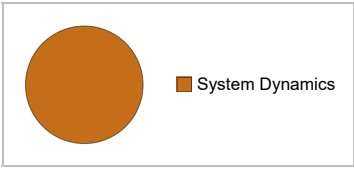
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
    Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 8.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_8"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_8
	D	More abundant non-recoverable natural resources, birth control, and stable industrial output
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

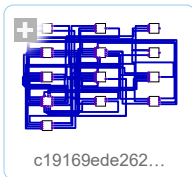
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

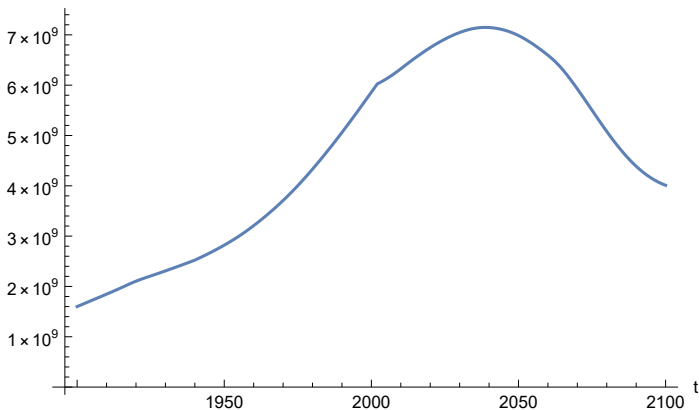
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Wc19169ede26243ec920f178031a641c1  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

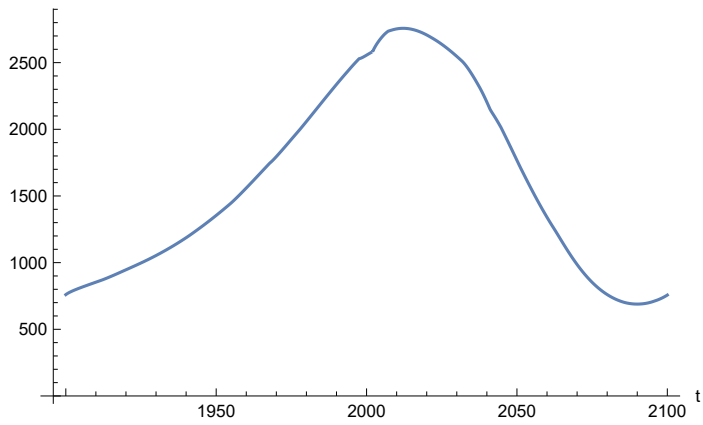
```
In[22]:= MinAndMax[basesim [{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.1478 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

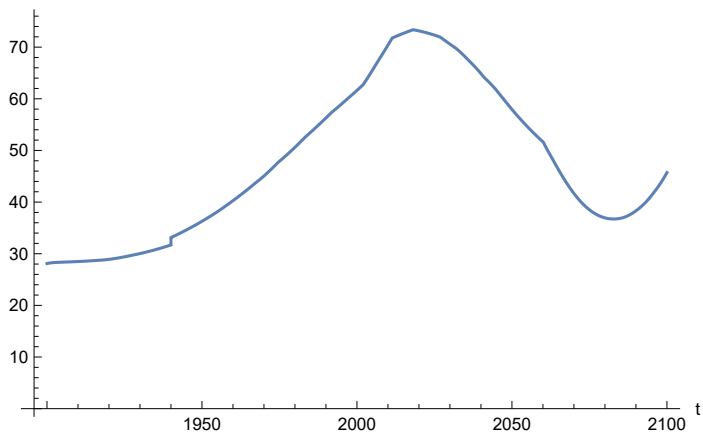
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

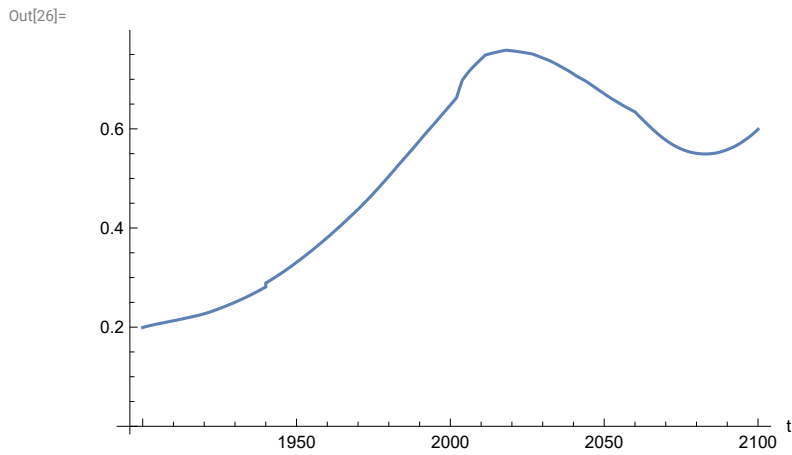
Out[24]=



In[25]:=

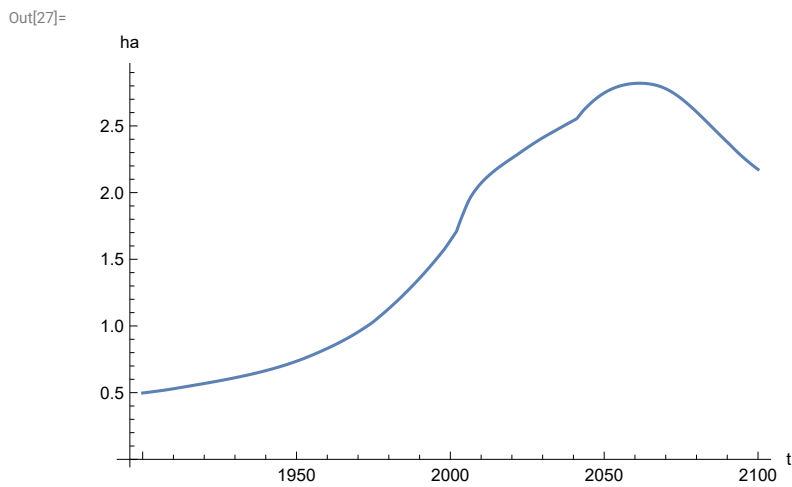
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



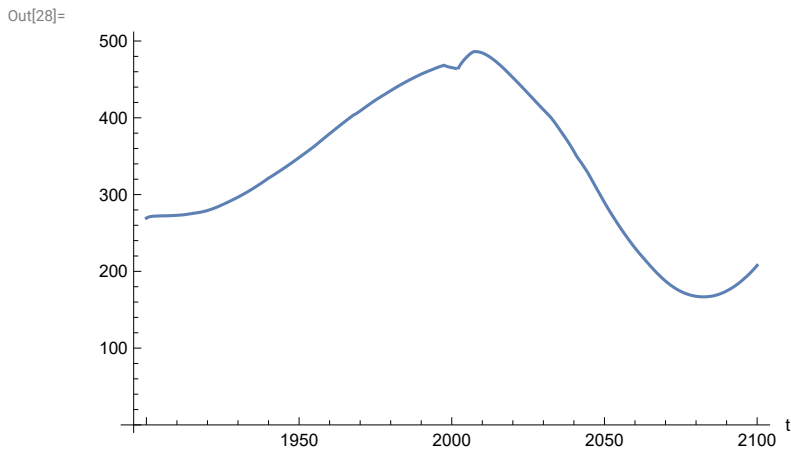
Plot per capita ecological footprint, hectares.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



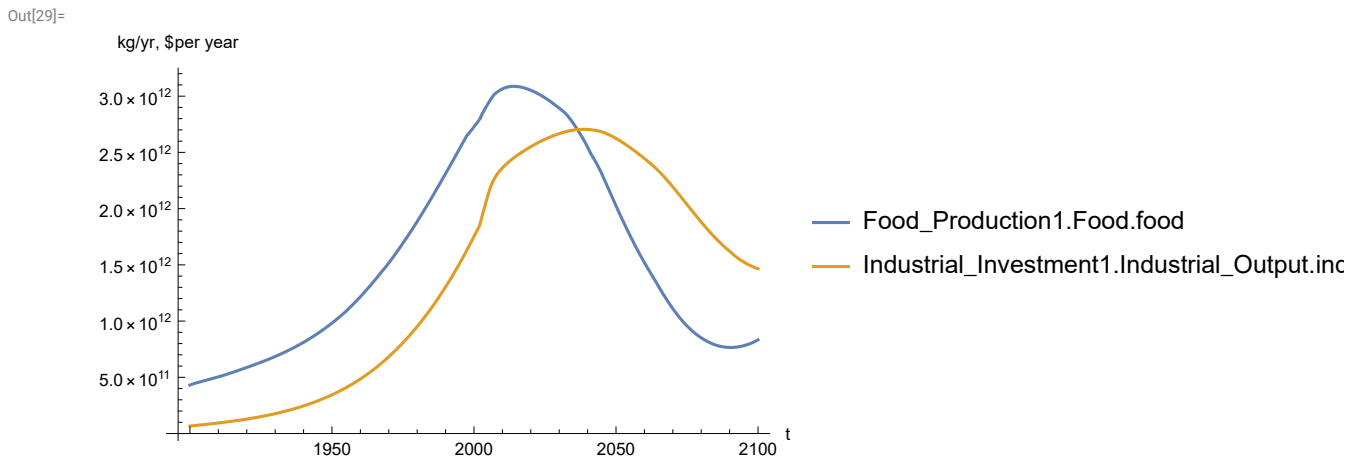
Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]



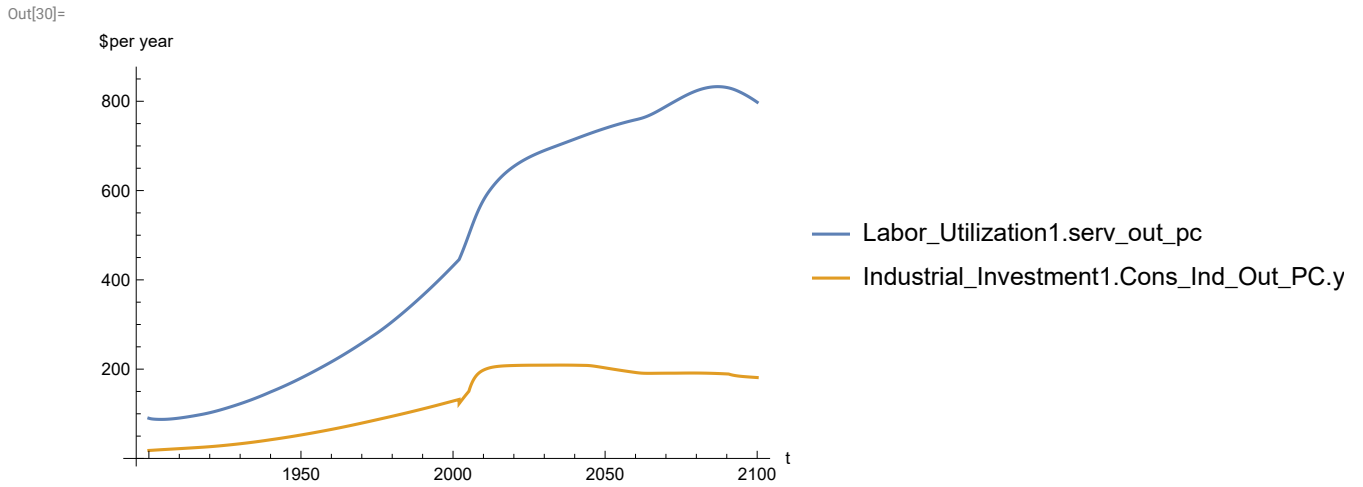
Plot total food production (kg/year), and industrial output (dollars/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

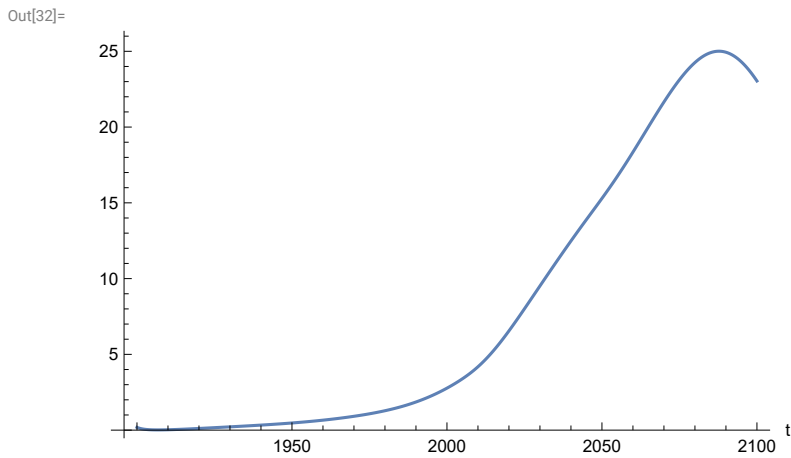


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 832.785
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

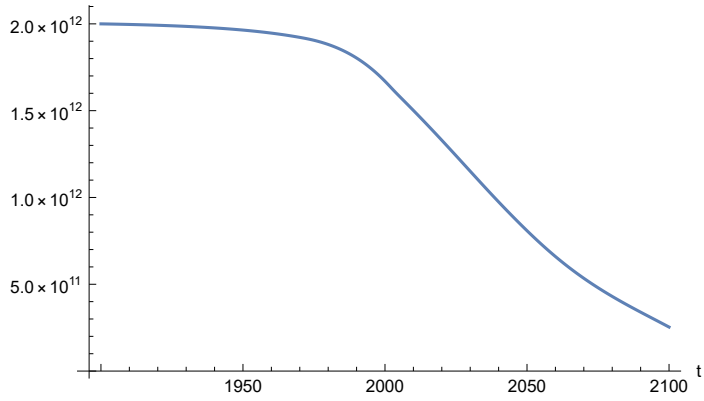


Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 25.0064
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[ ]:=
```



**APPENDIX 105. BENCHMARK SCENARIO 9, Experiment 105. t_policy_year = 2002.
Last modified: 31 July 2022/0900 US CT**

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

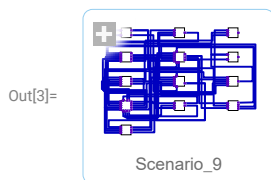
```
In[1]:= RangeData[data_] := data[[1]][4][3];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

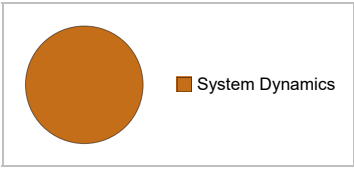
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 9.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_9"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_9
	D	Combining the measures of Scenarios #6 and #8
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show the default value of `t_policy_year`.

In[5]:= **SystemModel[mysim][{"ParameterValues", "t_policy_year"}]**

Out[5]= {t_policy_year → 2002}

Show `Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals`.

In[6]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[7]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[8]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[9]:= **SystemModel[mysim][{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[12]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[12]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute scenario and plot various variables

```
In[20]:= basesim = SystemModelSimulate[mysim]
```

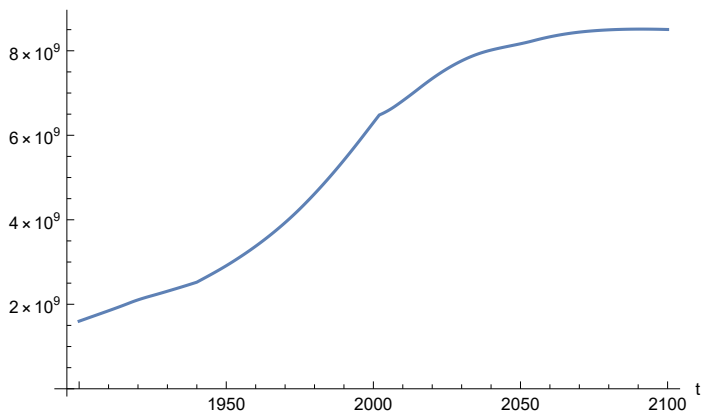
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Scenario_9
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

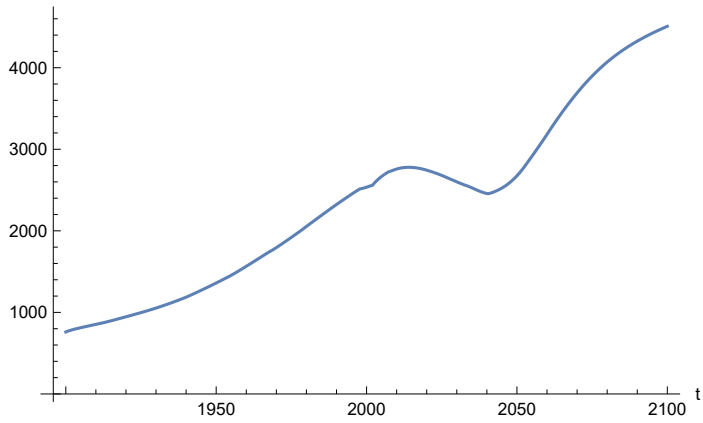
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.51279 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

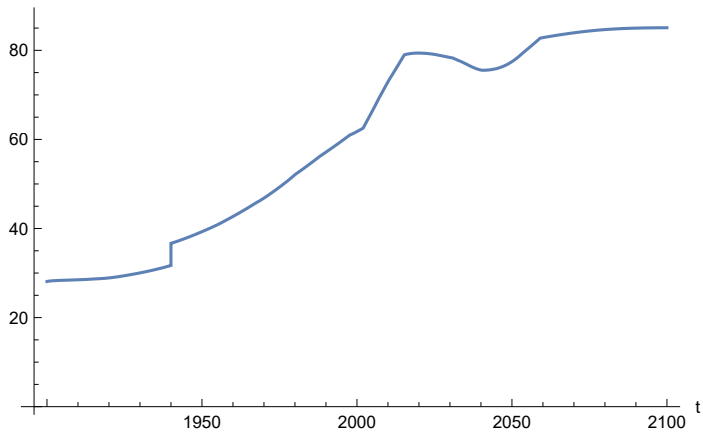
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

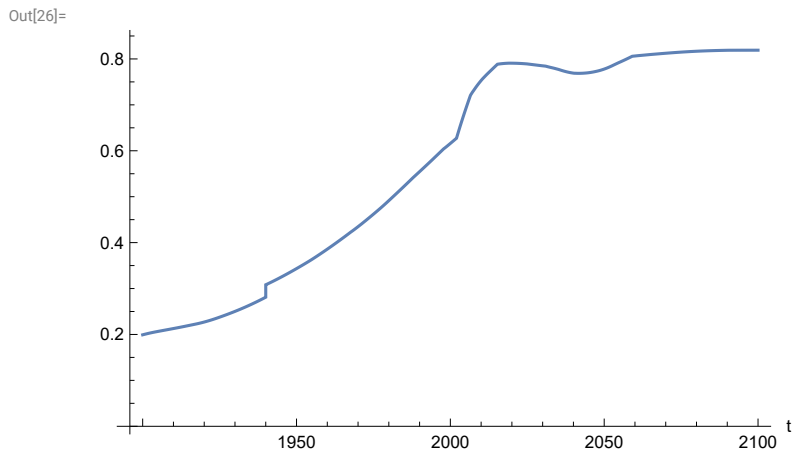
Out[24]=



In[25]:=

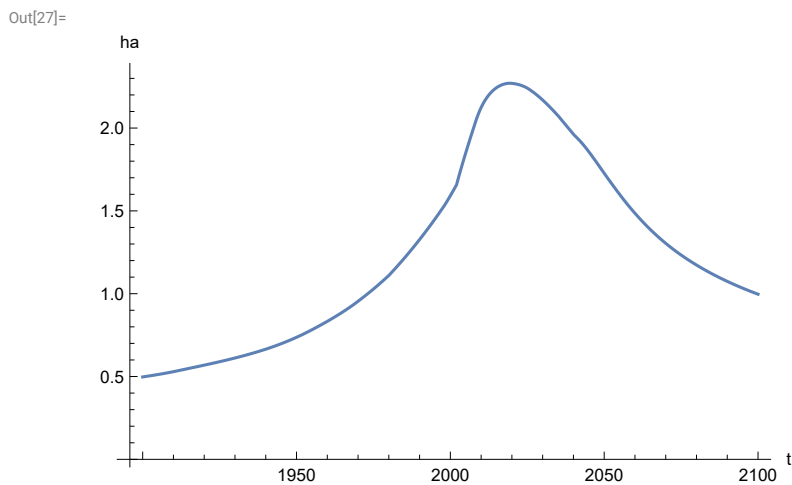
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

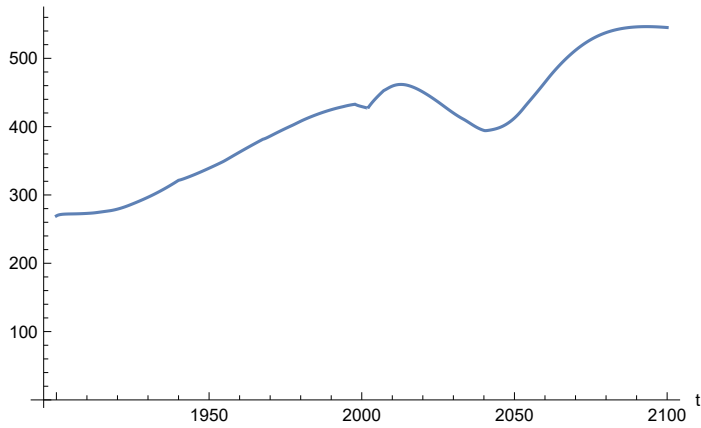
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

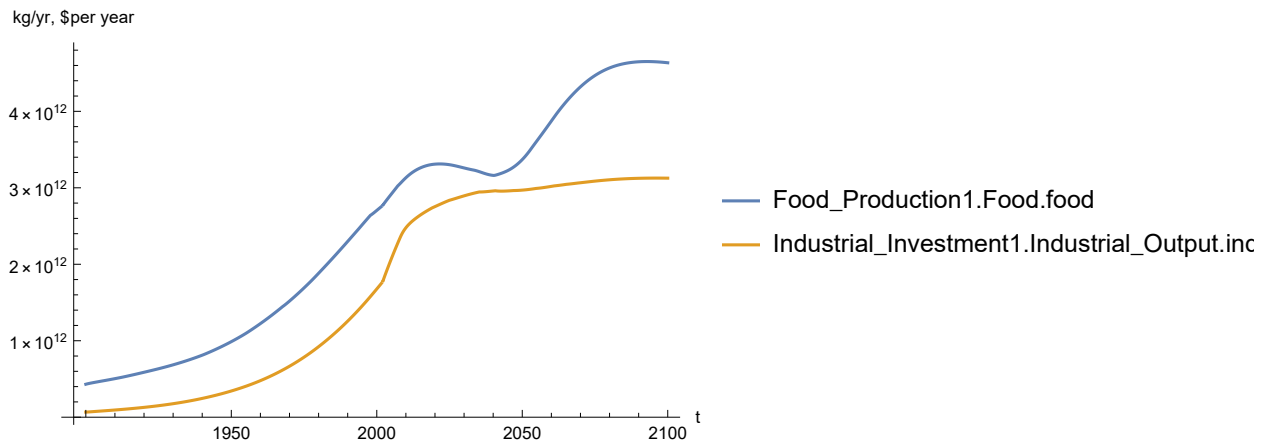
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

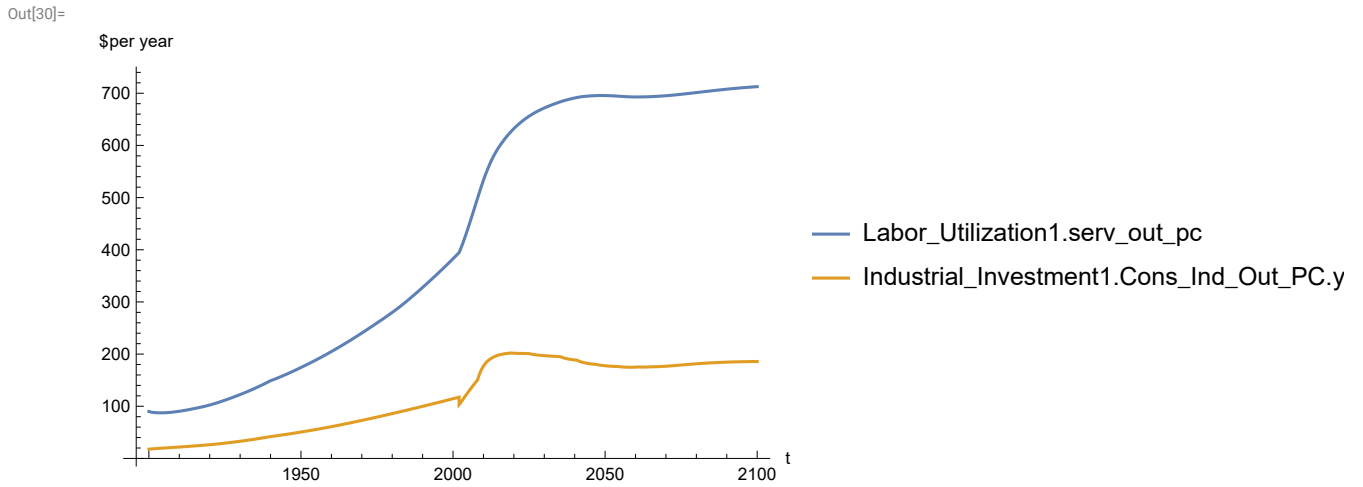
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

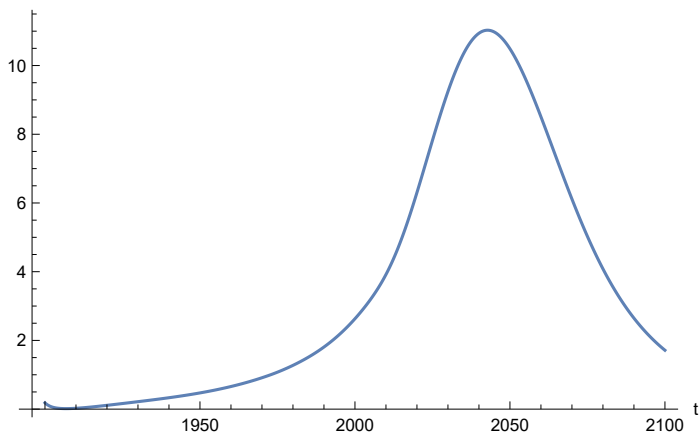


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 712.65
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[32]=
```



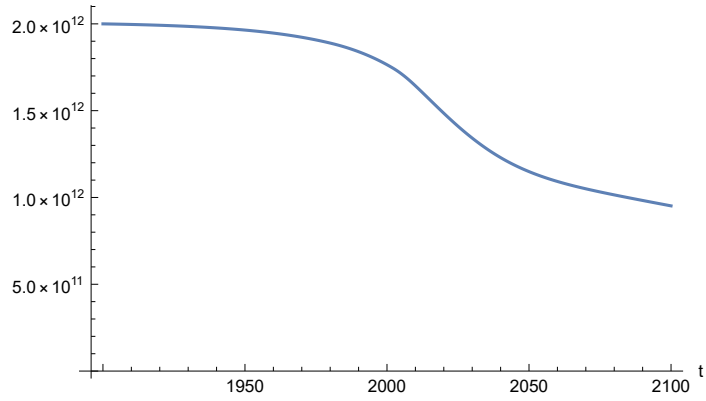
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.028
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

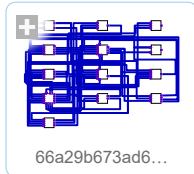


APPENDIX 106. $t_policy_year = 1970$, Benchmark Scenario 9, Experiment 106

Change the value of t_policy_year to 1970, execute the resulting scenario, and plot various variables.


```
In[35]:= newmysim1970 = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[35]=
```



```
In[36]:= testsim1970 = SystemModelSimulate[newmysim1970]
```

```
Out[36]=
```

```
SystemModelSimulationData [  Model: W66a29b673ad64affbb6c0117e75efc82  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Show the value of t_policy_year .

```
In[37]:= SystemModel[newmysim1970][{"ParameterValues", "t_policy_year"}]
```

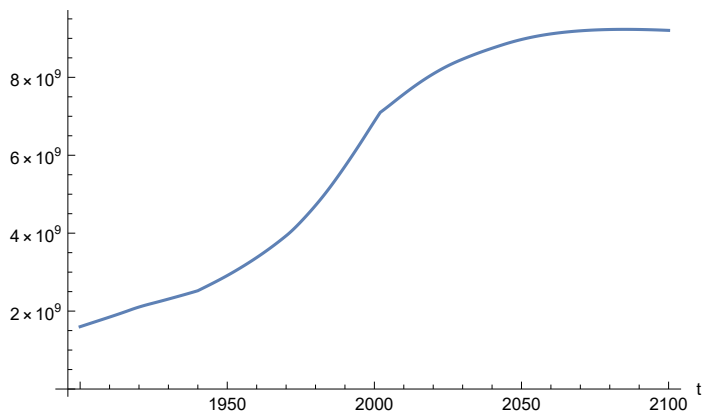
```
Out[37]=
```

```
{t_policy_year → 1970}
```

Plot the world population, people.

```
In[38]:= SystemModelPlot[testsim1970, {"Population_Dynamics1.Birth_Rate.pop"}]
```

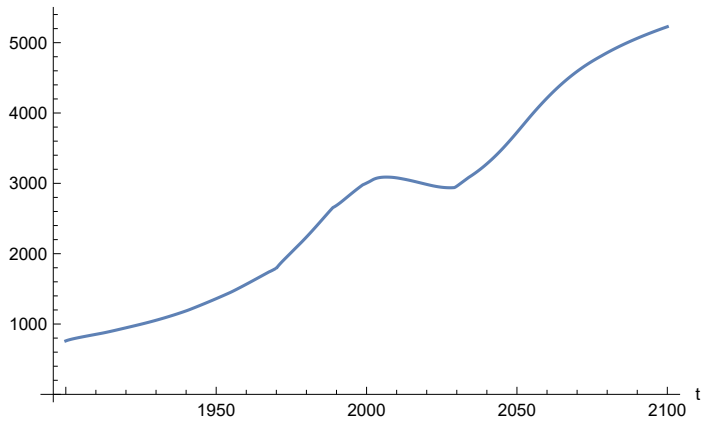
```
Out[38]=
```



Find max and min of y values.

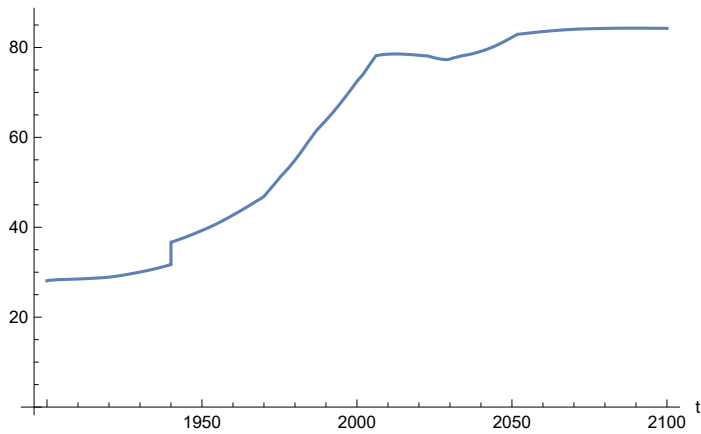
```
In[39]:= MinAndMax[testsim1970[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $9.23113 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[40]:= SystemModelPlot[testsim1970, {"Food_Production1.Land_Yield.y"}]
Out[40]=
```



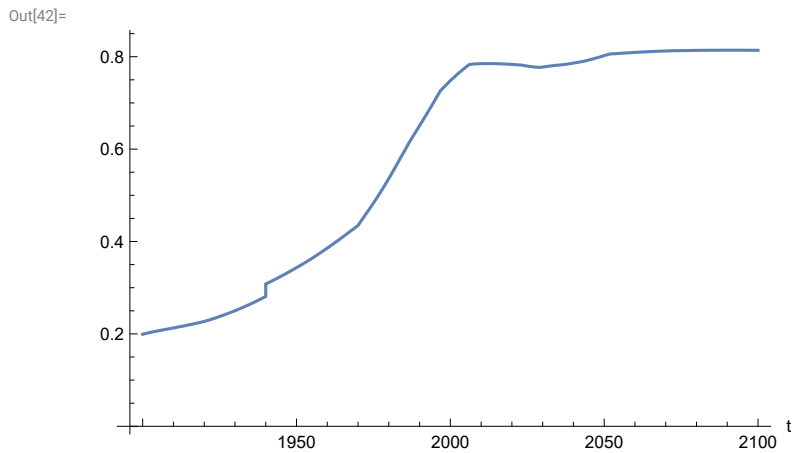
Plot life expectancy, in years.

```
In[41]:= SystemModelPlot[testsim1970, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[41]=
```



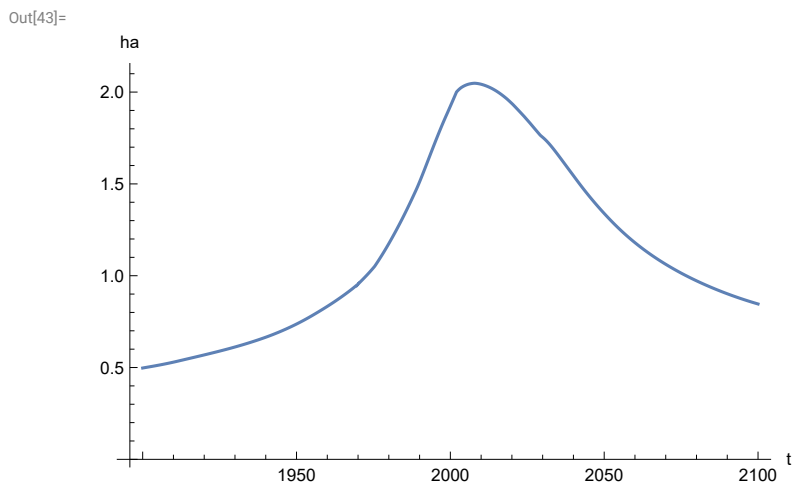
Plot the human welfare index.

```
In[42]:= SystemModelPlot[testsim1970,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot the human ecological footprint, in hectares.

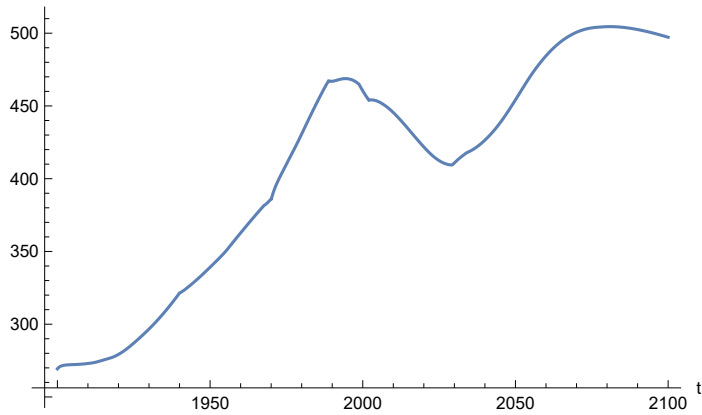
```
In[43]:= SystemModelPlot[testsim1970,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot per capita food production, kg/year.

In[44]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food_PC.y"}]**

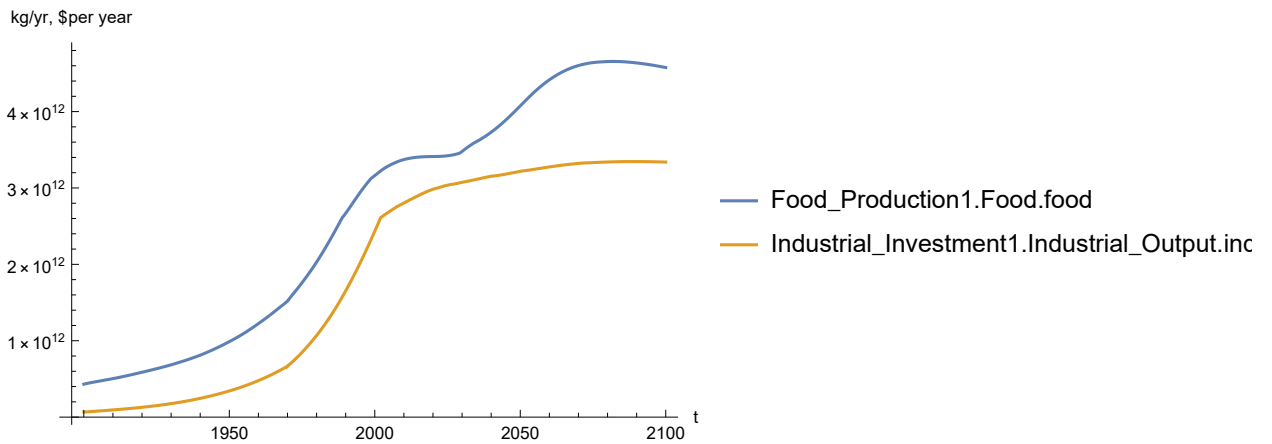
Out[44]=



Plot total food production (kg/yr) and industrial output (in dollars).

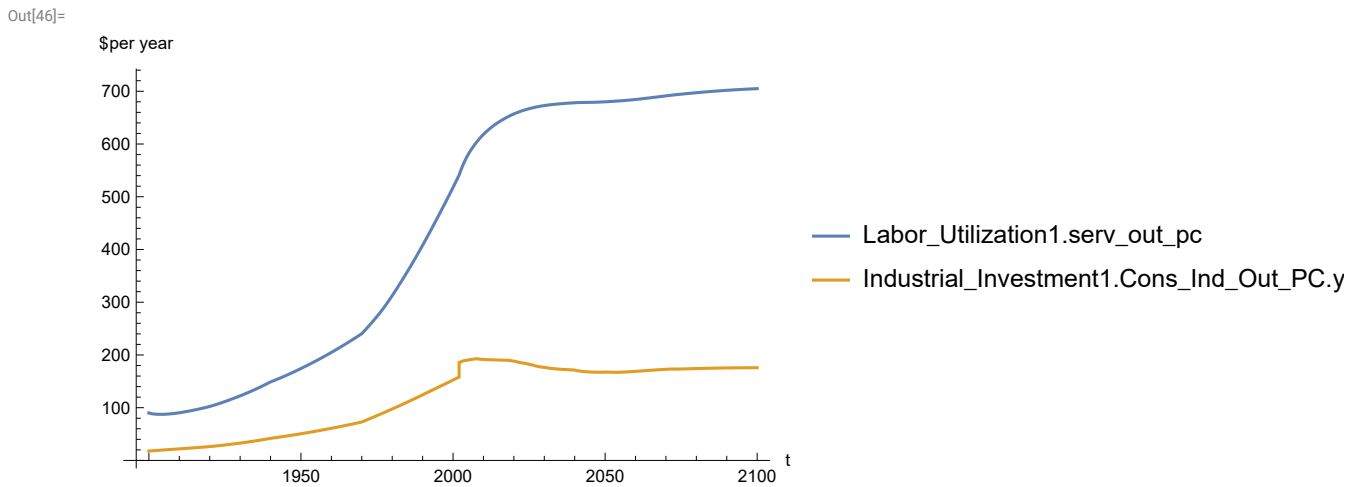
In[45]:= **SystemModelPlot[testsim1970, {"Food_Production1.Food.food", "Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[45]=



Plot labor utilization and consolidated industrial output per capita (dollars/year).

```
In[46]:= SystemModelPlot[testsim1970,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```



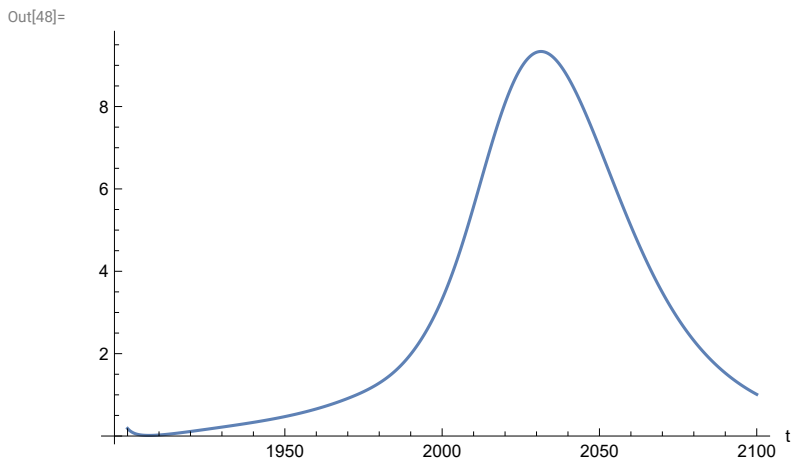
Find max and min of y values.

```
In[47]:= MinAndMax[testsim1970[{"Labor_Utilization1.serv_out_pc"}]]
```

Maximum is 704.969
 Minimum is 87.4451

Plot persistent pollution index (normalized to 1970 value).

```
In[48]:= SystemModelPlot[testsim1970, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

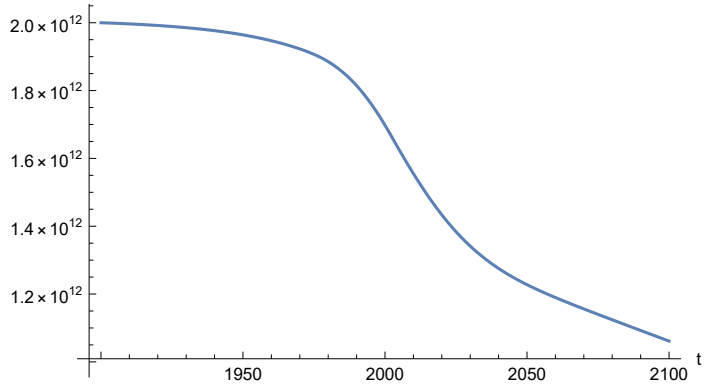
```
In[49]:= MinAndMax[testsim1970[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 9.33693
 Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[50]:= SystemModelPlot[testsim1970, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

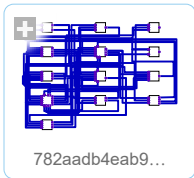
Out[50]=



APPENDIX 107. Benchmark Scenario 9, $t_{\text{policy_year}} = 2025$. Experiment 107.

Change the value of the air pollution effect multiplier switch time $t_{\text{policy_year}}$, to calendar year 2025, and execute the resulting scenario, plotting the variables shown in Figure 2.

```
In[51]:= newmysim = SystemModel[mysim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
Out[51]=
```



```
In[52]:= testsim = SystemModelSimulate[newmysim]
Out[52]=
```

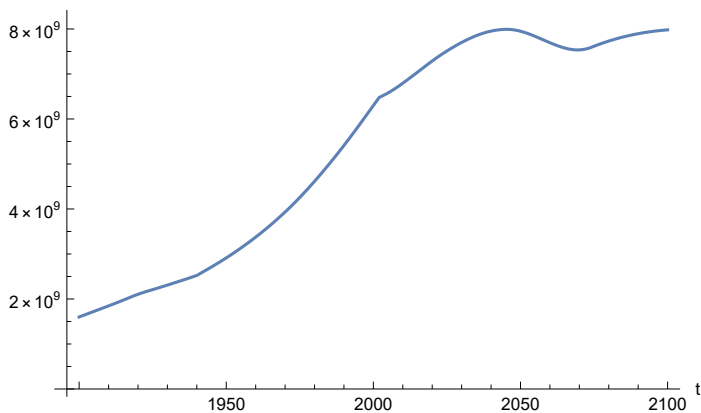
```
SystemModelSimulationData [ { Model: W782aadb4eab94094a386836c857759fc
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  } ]
```

Show the value of $t_{\text{policy_year}}$.

```
In[53]:= SystemModel[newmysim][{"ParameterValues", "t_policy_year"}]
Out[53]= {t_policy_year → 2025}
```

Plot the world population, people.

```
In[54]:= SystemModelPlot[testsim, {"Population_Dynamics1.Birth_Rate.pop"}]
Out[54]=
```

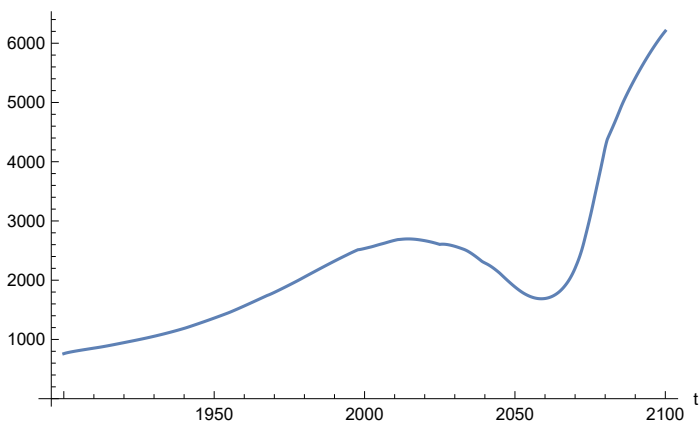


Find max and min of y values.

```
In[55]:= MinAndMax[testsim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.99206 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

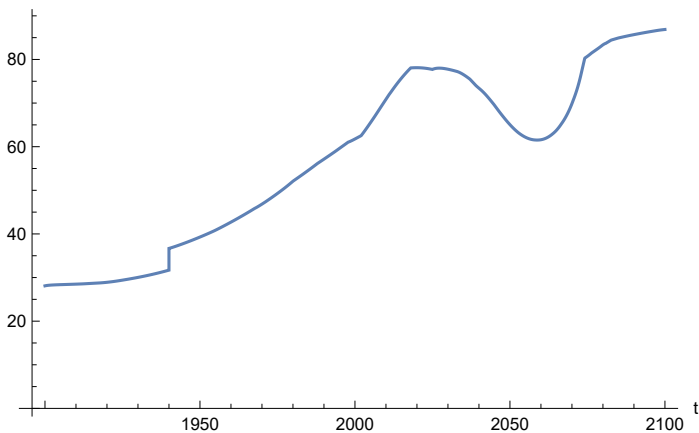
Plot land yield.

```
In[56]:= SystemModelPlot[testsim, {"Food_Production1.Land_Yield.y"}]
Out[56]=
```



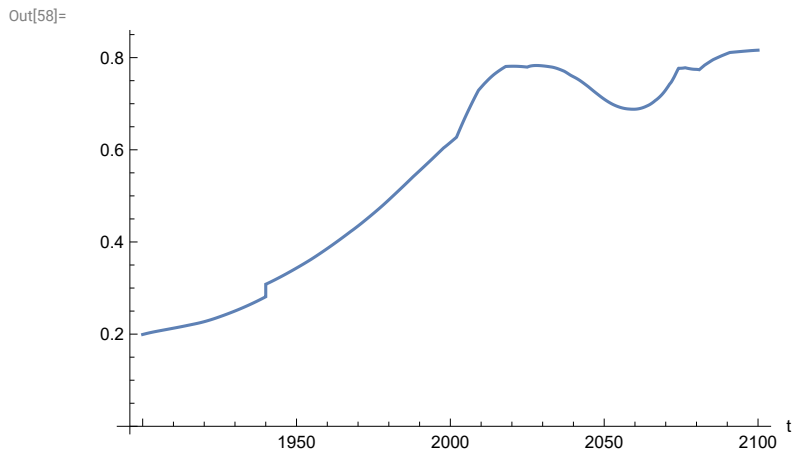
Plot life expectancy, in years.

```
In[57]:= SystemModelPlot[testsim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[57]=
```



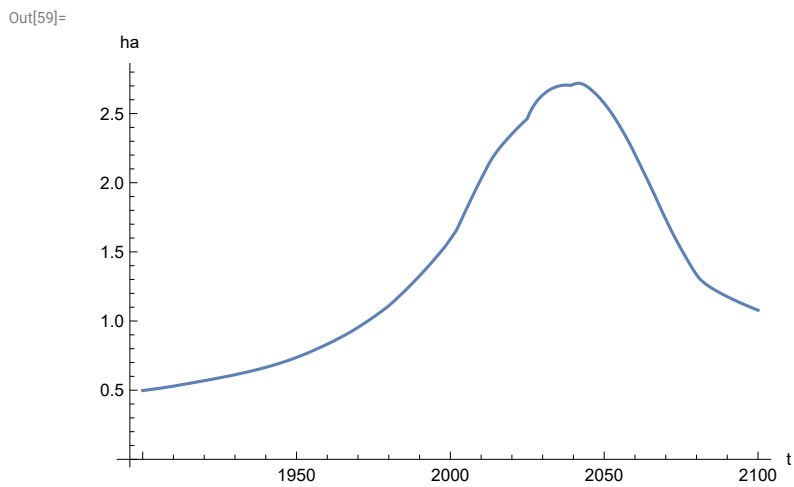
Plot the human welfare index.

```
In[58]:= SystemModelPlot[testsim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



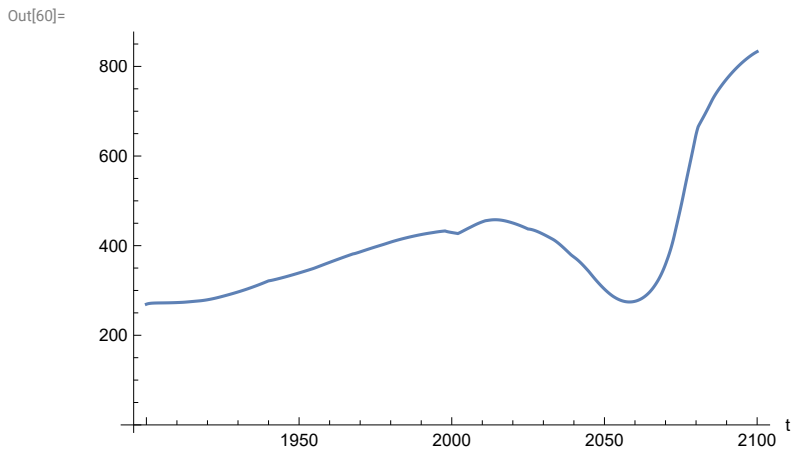
Plot the human ecological footprint, in hectares.

```
In[59]:= SystemModelPlot[testsim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



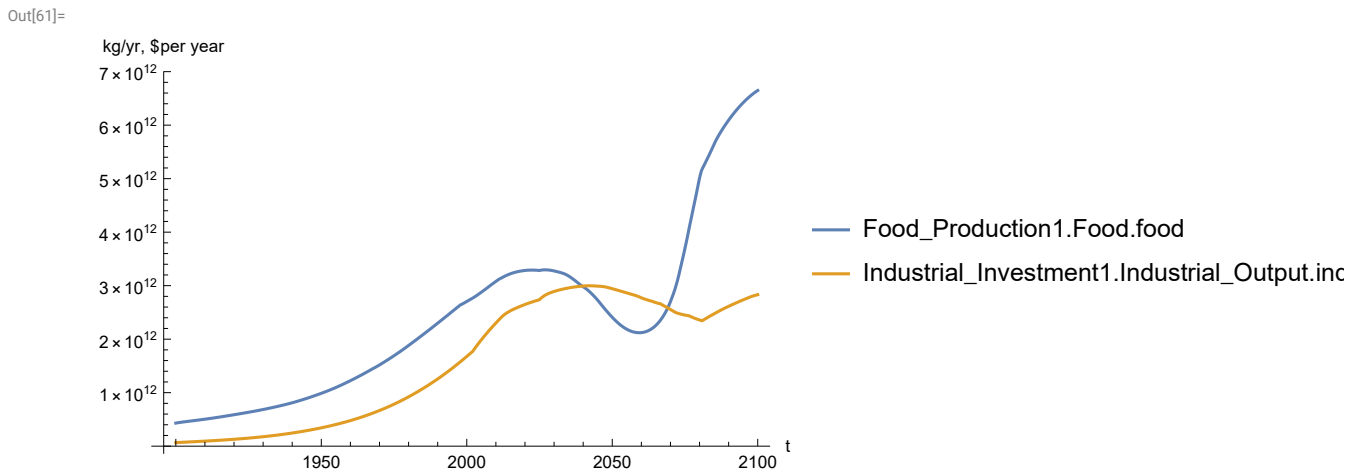
Plot per capita food production, kg/year.

```
In[60]:= SystemModelPlot[testsim, {"Food_Production1.Food_PC.y"}]
```



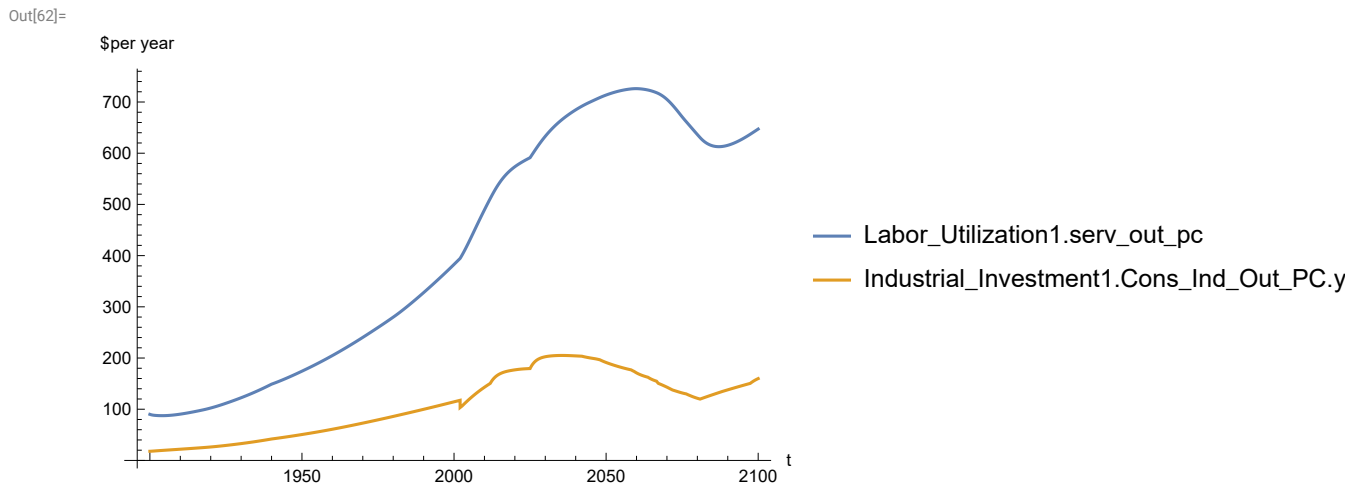
Plot total food production (kg/yr) and industrial output (in dollars).

```
In[61]:= SystemModelPlot[testsim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```



Plot consolidated industrial output per capita (dollars/year).

```
In[62]:= SystemModelPlot[testsim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

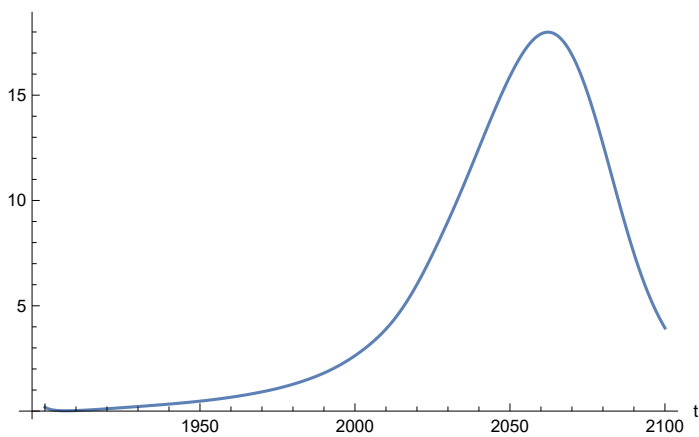


Find max and min of y values.

```
In[63]:= MinAndMax[testsim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 726.096
Minimum is 87.4451
```

Plot persistent pollution index (normalized to 1970 value).

```
In[64]:= SystemModelPlot[testsim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[64]=
```

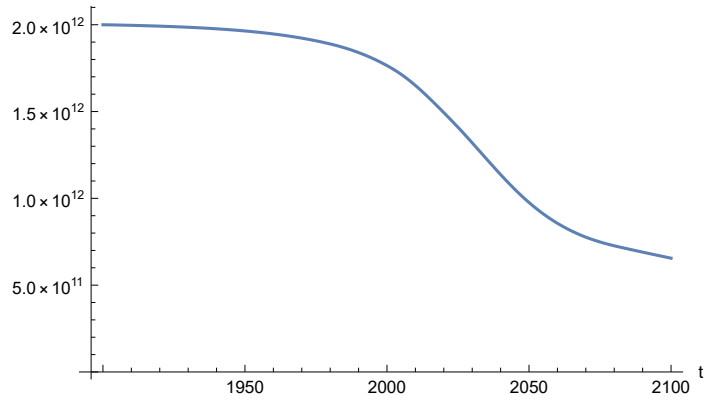


Find max and min of y values.

```
In[65]:= MinAndMax[testsim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 17.991
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[66]:= SystemModelPlot[testsim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[66]=
```



APPENDIX 108. BENCHMARK SCENARIO 9, Experiment 108. $LE = LE/1.001$, $t_policy_year = 1970$.

Last modified: 31 July 2022/0920 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

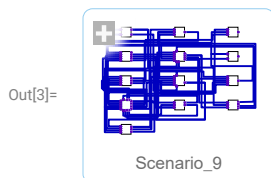
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

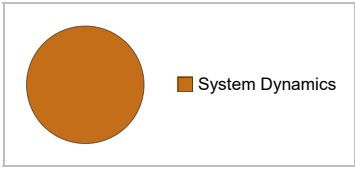
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 9.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_9"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_9
	Description	Combining the measures of Scenarios #6 and #8
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

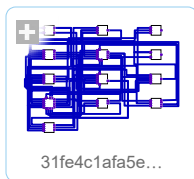
```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

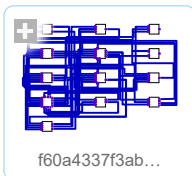
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970} |>]
```

```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

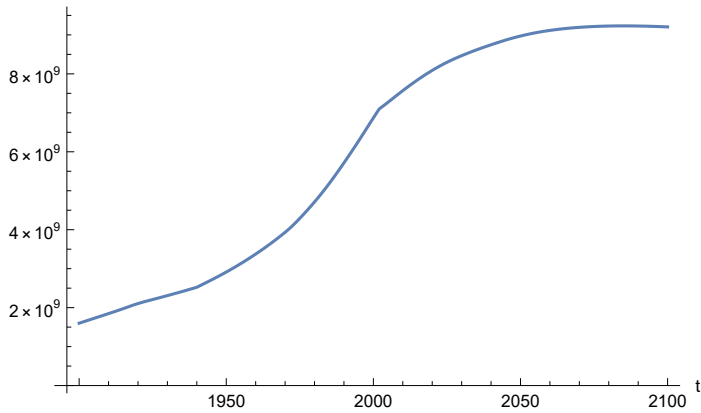
```
Out[21]=
```

```
SystemModelSimulationData [  Model: Wf60a4337f3ab4cc88f794a5e74224fef  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

In[22]:= **SystemModelPlot**[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]

Out[22]=



Find max and min of population values.

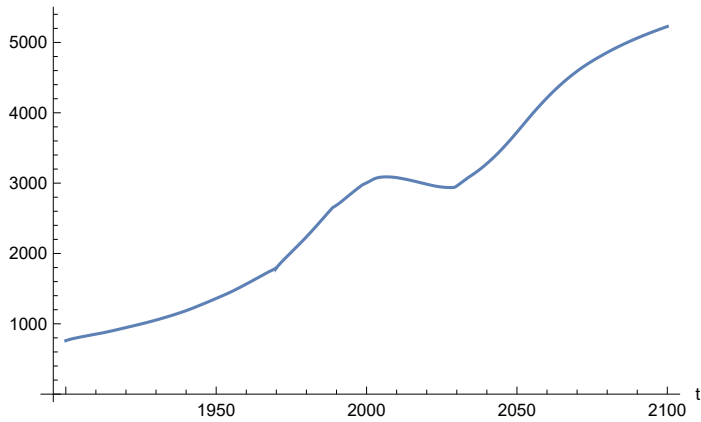
In[23]:= **MinAndMax**[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]

Maximum is 9.23113×10^9

Minimum is 1.6×10^9

In[24]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

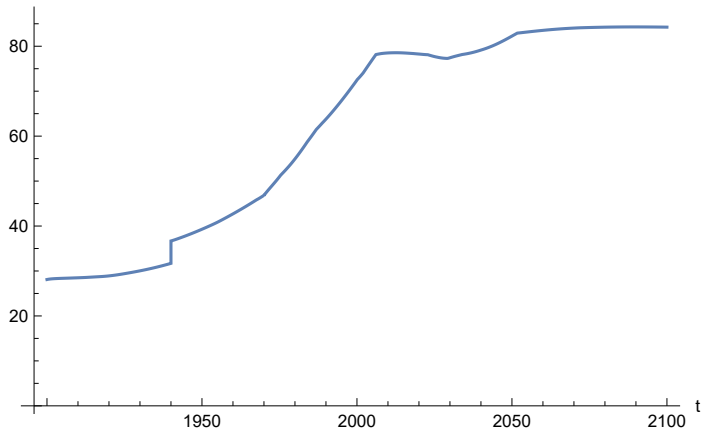
Out[24]=



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

Out[25]=

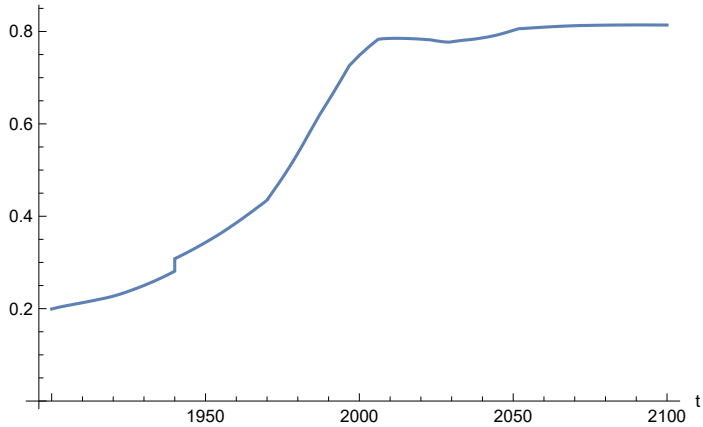


In[26]:=

Plot human welfare index.

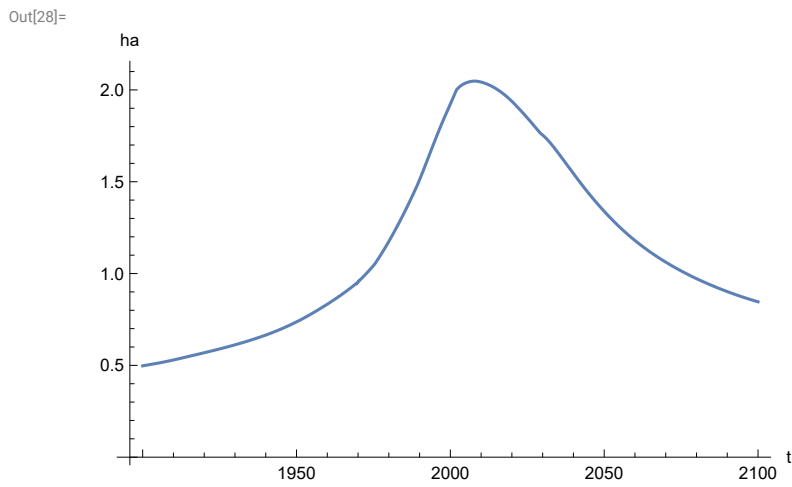
```
In[27]:= SystemModelPlot[basesim, {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

Out[27]=



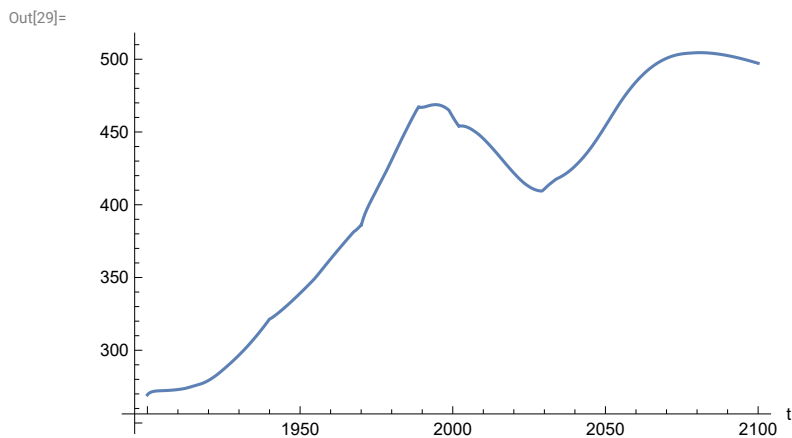
Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_
    _footprint"}]
```



Plot food production per capita (kg/year).

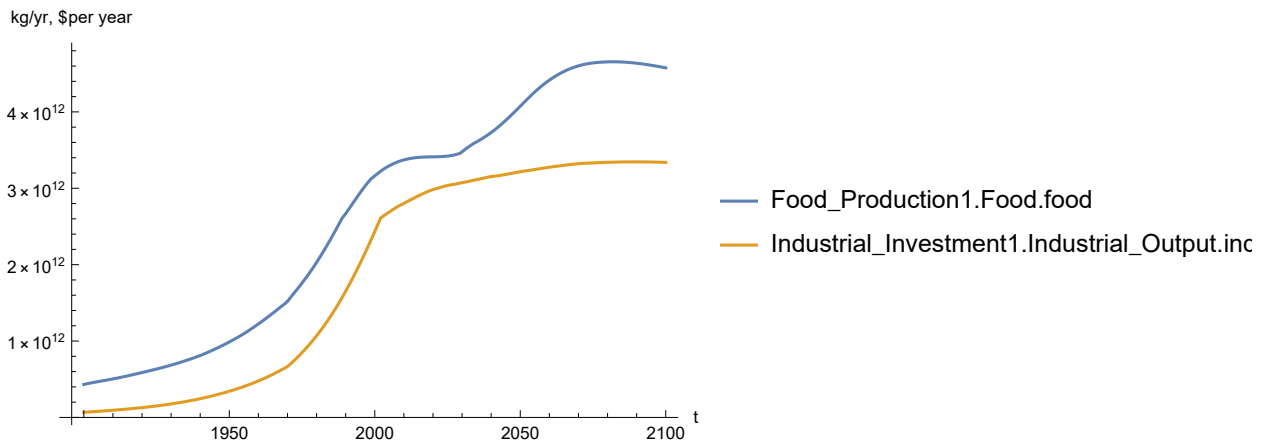
```
In[29]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[30]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

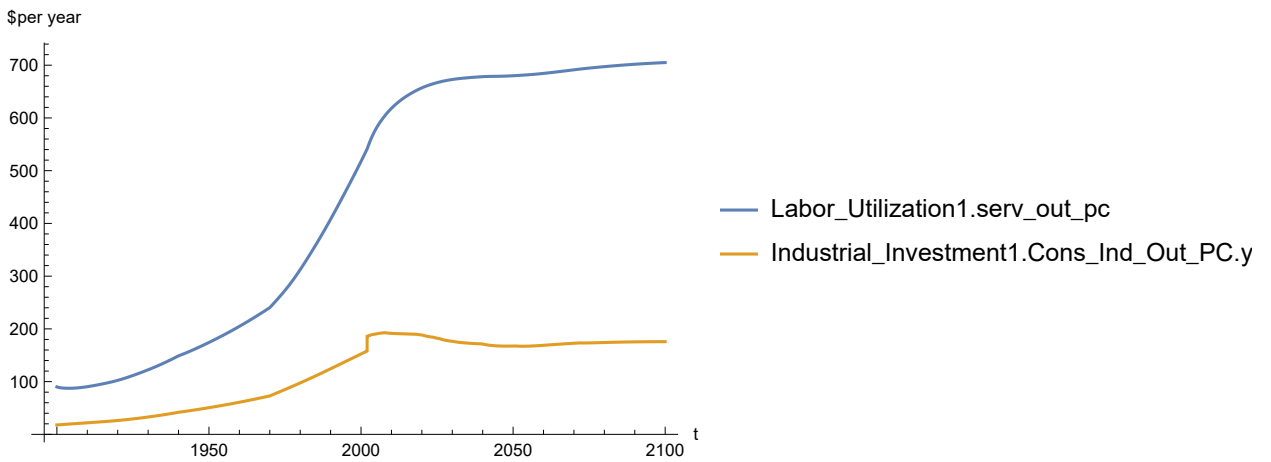
Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim, {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[31]=



Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

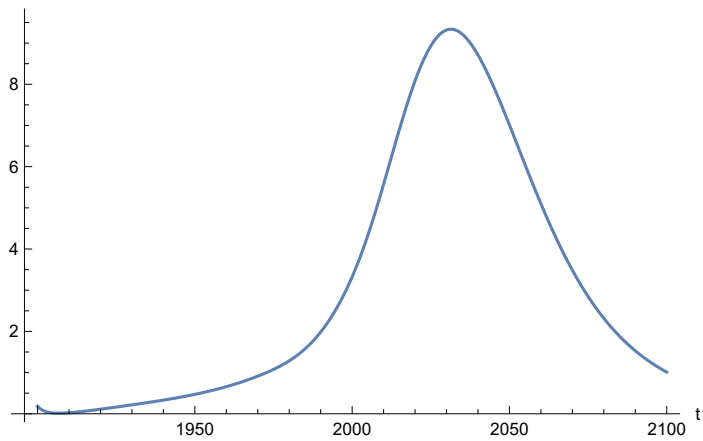
Maximum is 704.969

Minimum is 87.4451

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

```
Out[33]=
```



Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

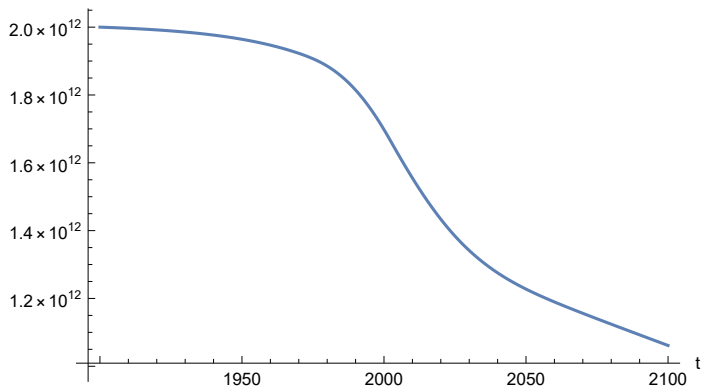
```
Maximum is 9.33693
```

```
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

```
Out[35]=
```

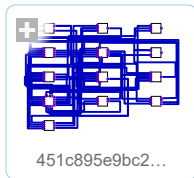


APPENDIX 109. LE/1.001, t_policy_year = 2025. Baseline Scenario 9, Experiment 109.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure default _Serv_2.y_vals

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

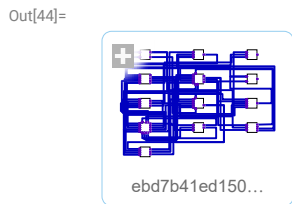
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
```



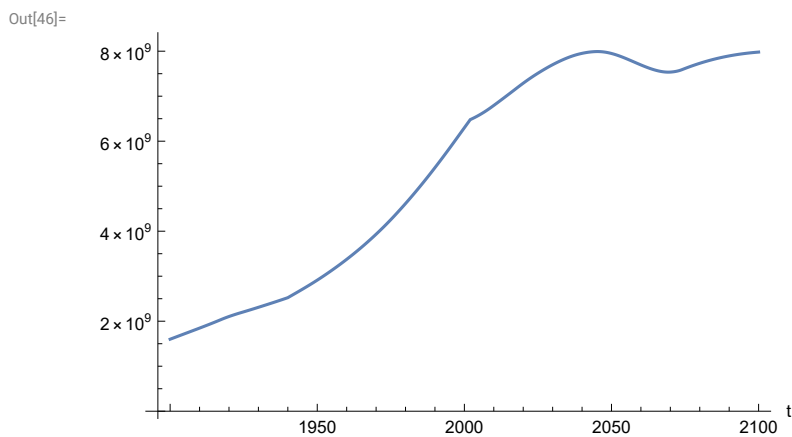
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: Webd7b41ed150475aa8ceee415c0b8e8b
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

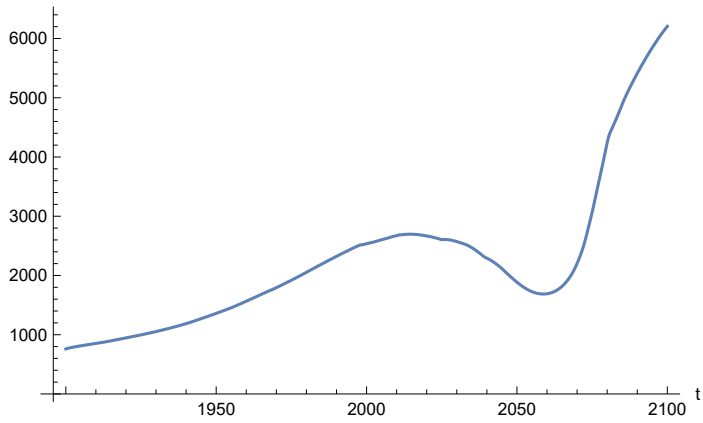
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.99206×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

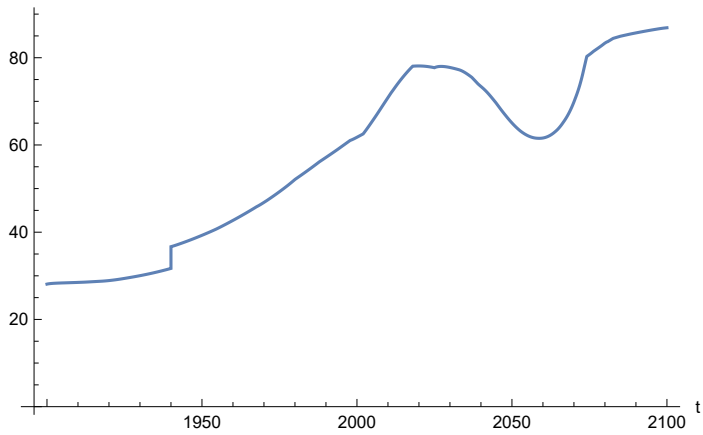
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

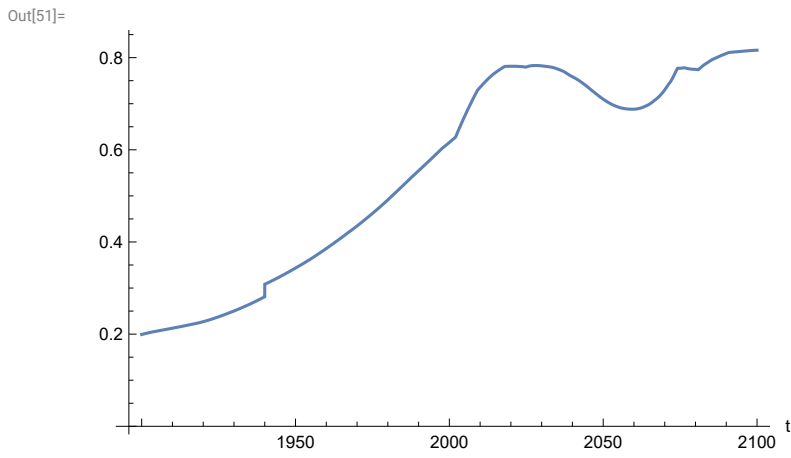
Out[49]=



In[50]:=

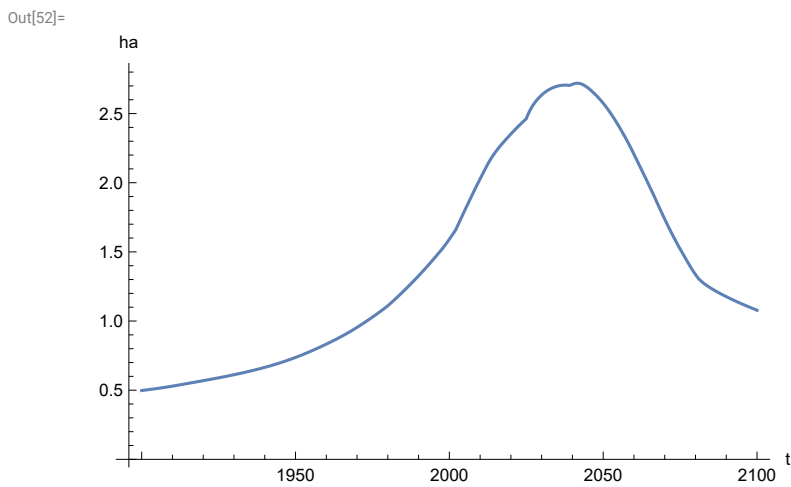
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

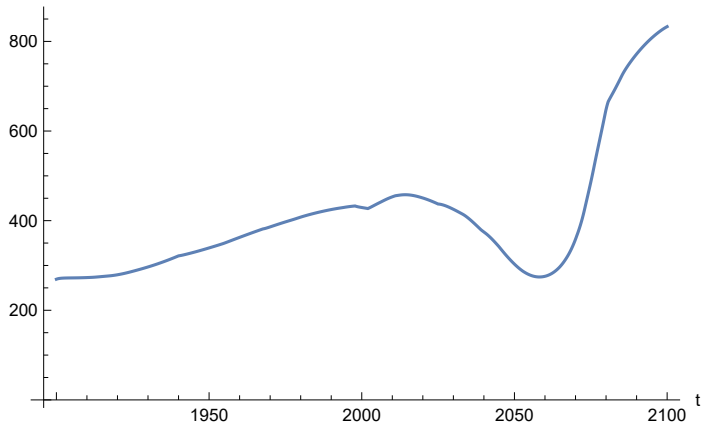
```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

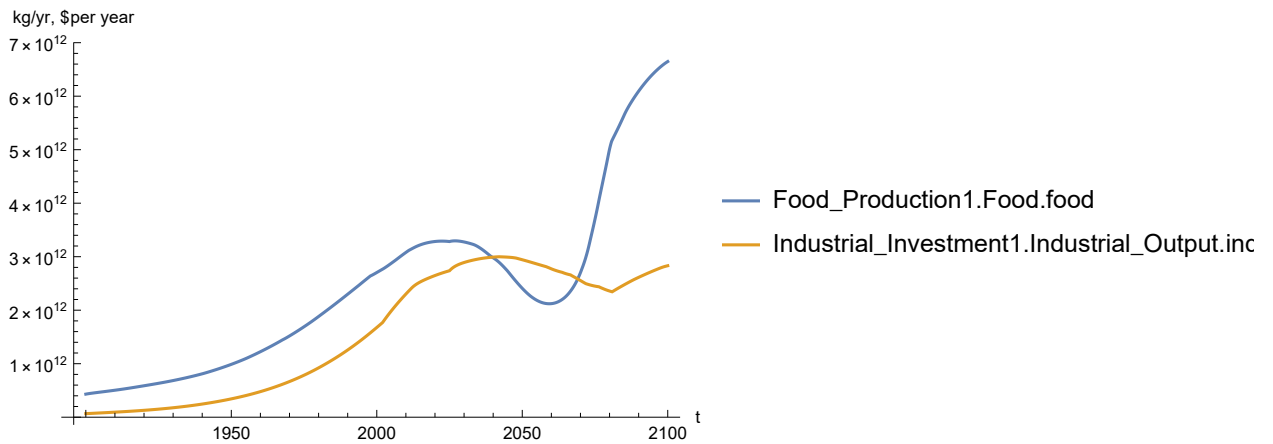
Out[53]=



Plot total food production (kg/year), and industrial output (dollars/year).

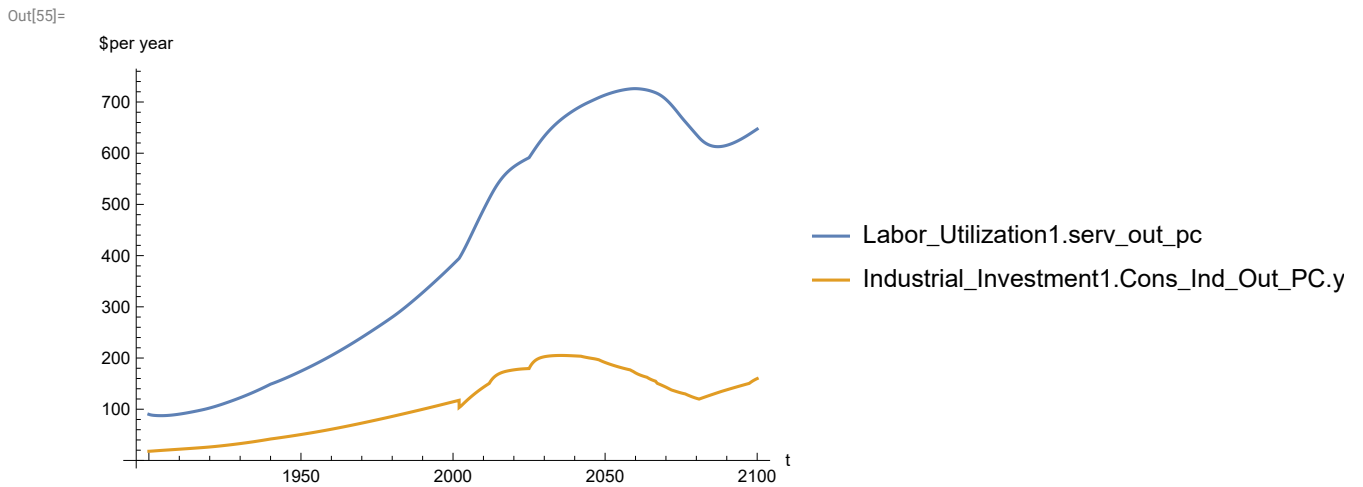
In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[54]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

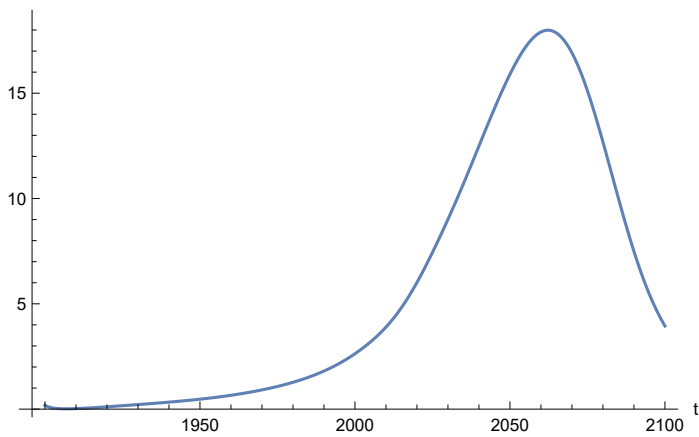


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 726.096
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



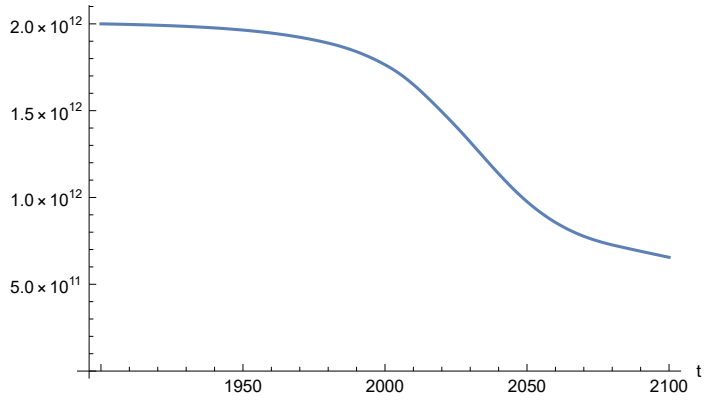
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 17.991
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

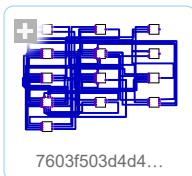


APPENDIX 110. LE/1.01, t_policy_year = 1970. Baseline Scenario 9, Experiment 110.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

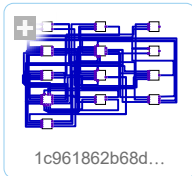
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set t_policy_year to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```


```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

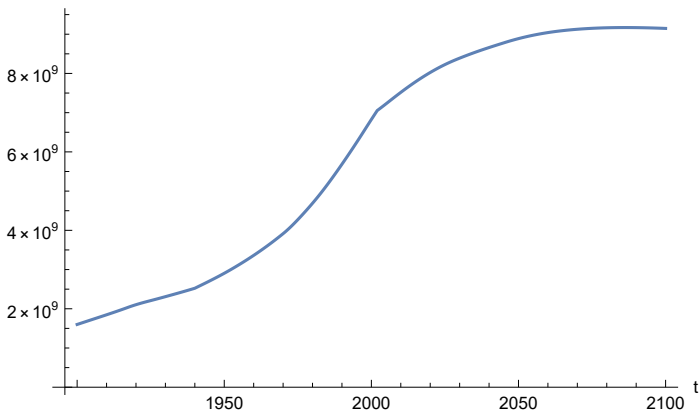
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W1c961862b68d49c9b9c9cfe13bbe2f37  
Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



Find max and min of population values.

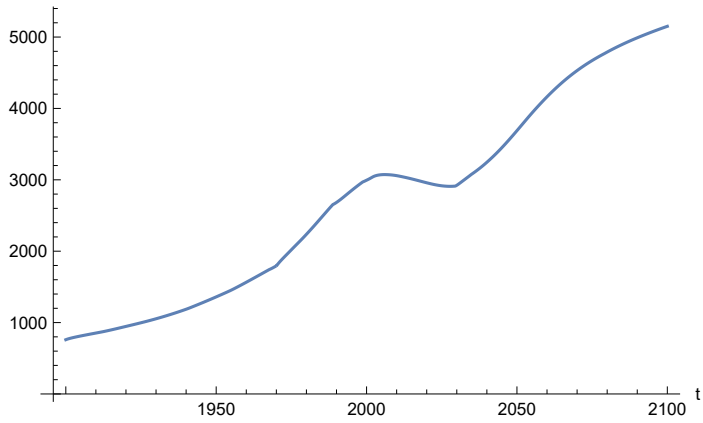
```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 9.16993 × 109
```

```
Minimum is 1.6 × 109
```

In[72]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

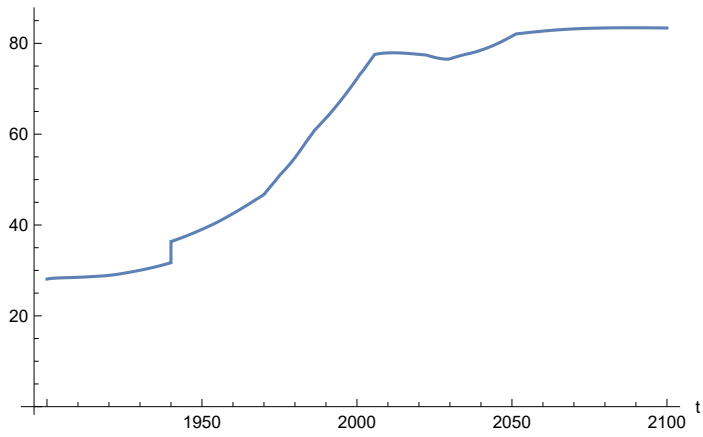
Out[72]=



Plot life expectancy, years.

In[73]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

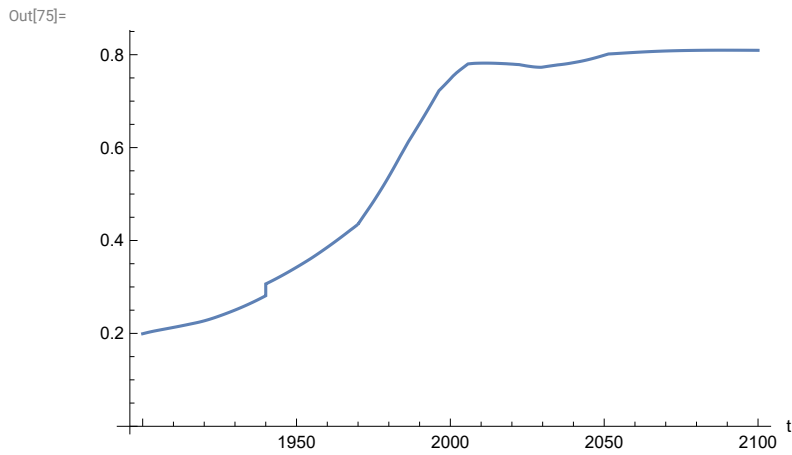
Out[73]=



In[74]:=

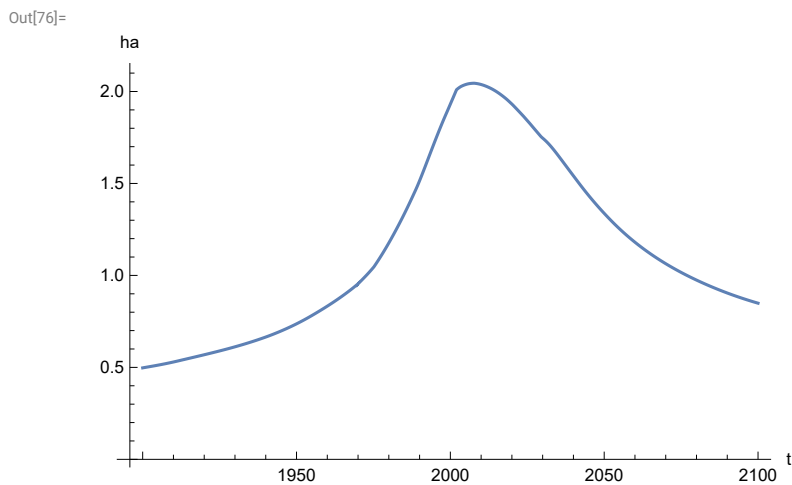
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

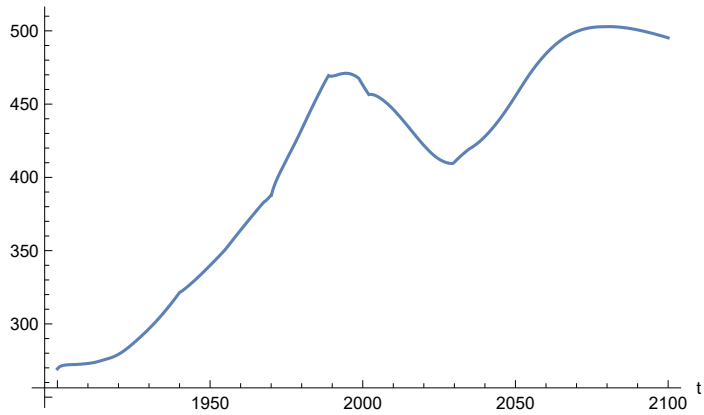
```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[77]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

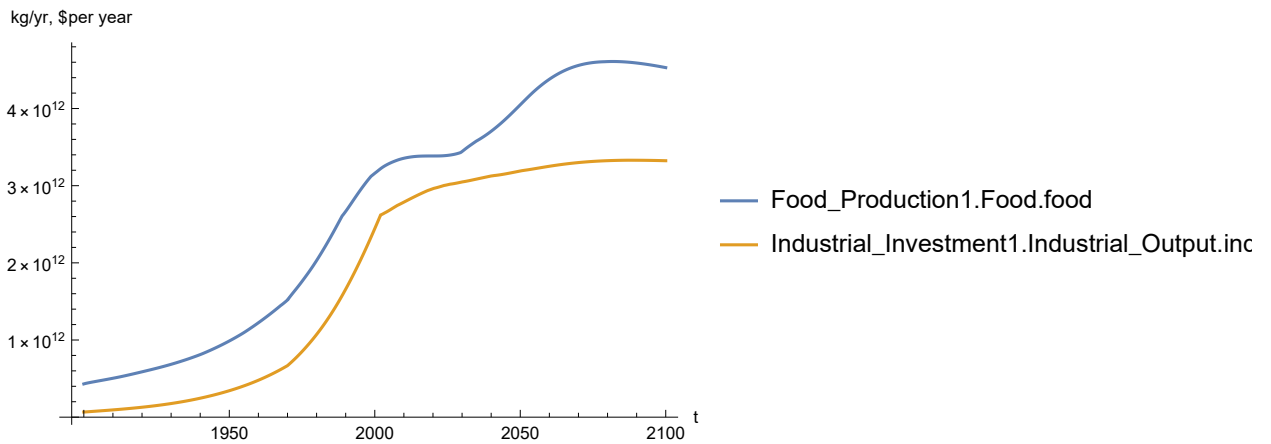
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[78]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

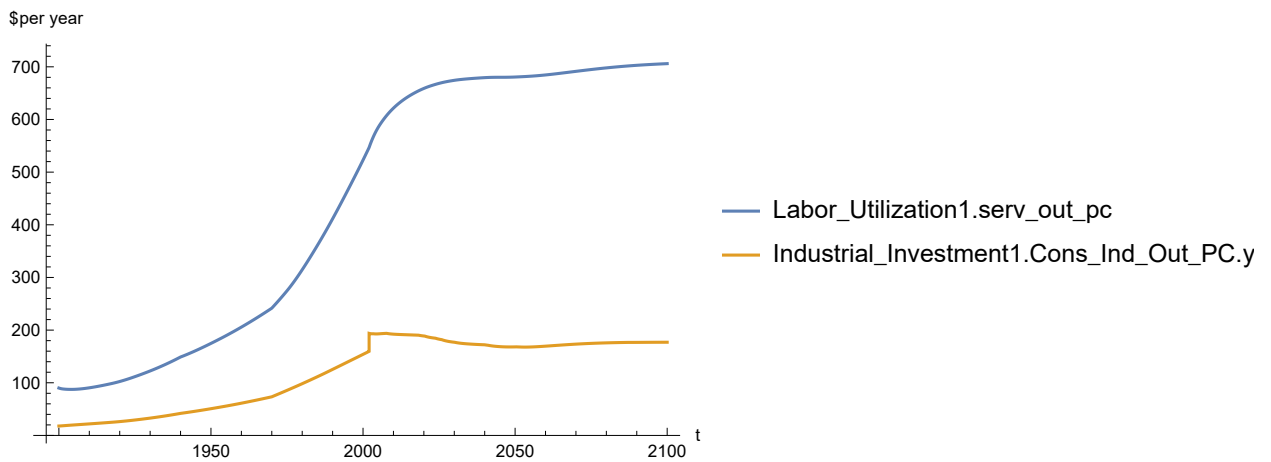
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

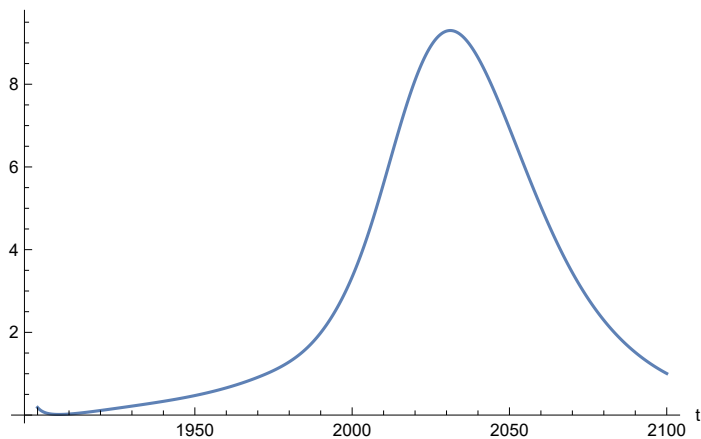
Maximum is 706.005

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

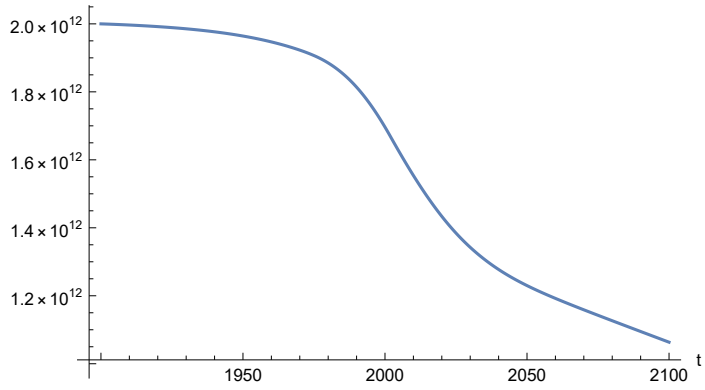
Maximum is 9.29897

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

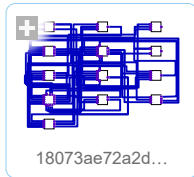
Out[83]=



APPENDIX 111. Baseline Scenario 9, Experiment 111. $LE = LE/1.01$, $t_{policy_year} = 2025$.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

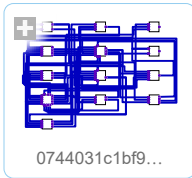
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

Set `t_policy_year` to 2025.



```
In[92]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
Out[92]=
```



Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

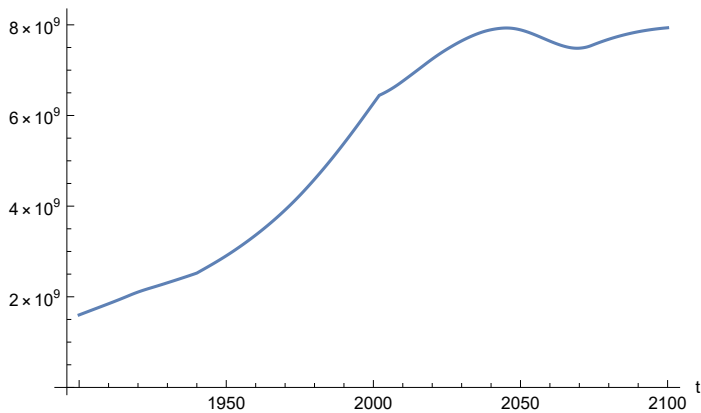
```
Out[93]=
```

```
SystemModelSimulationData [   Model: W0744031c1bf94361b51df8b9ad8ede11  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[94]=
```



Find max and min of population values.

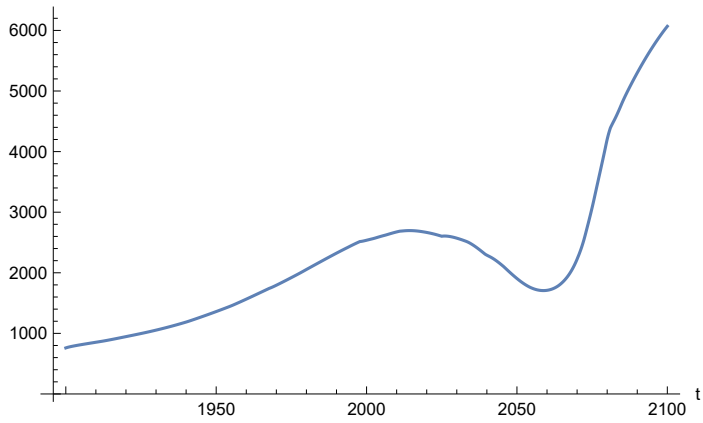
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.93533 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

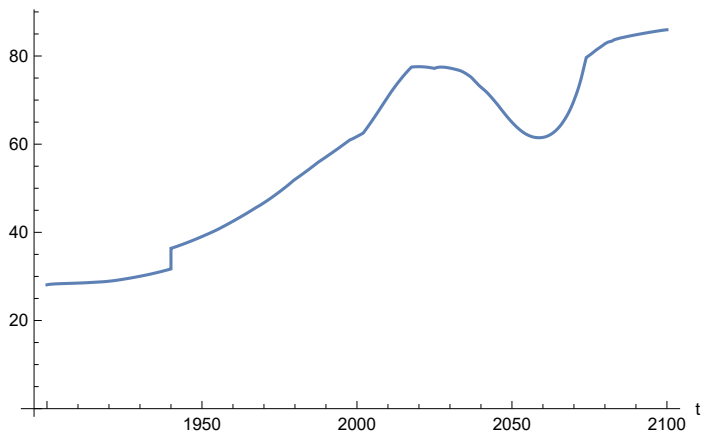
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

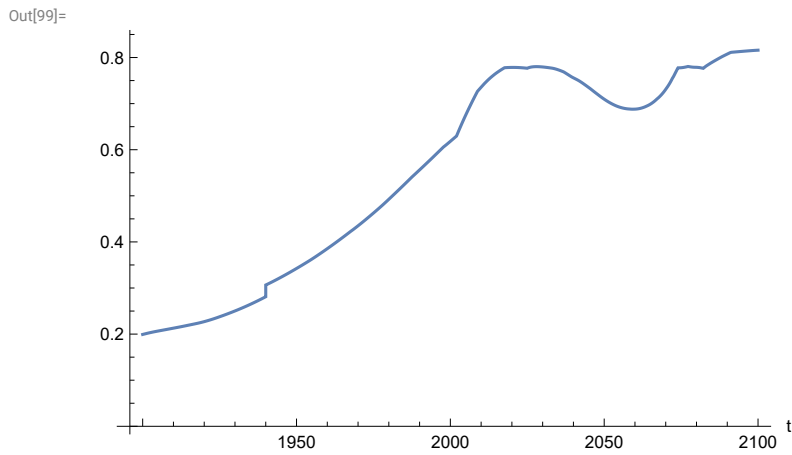
Out[97]=



In[98]:=

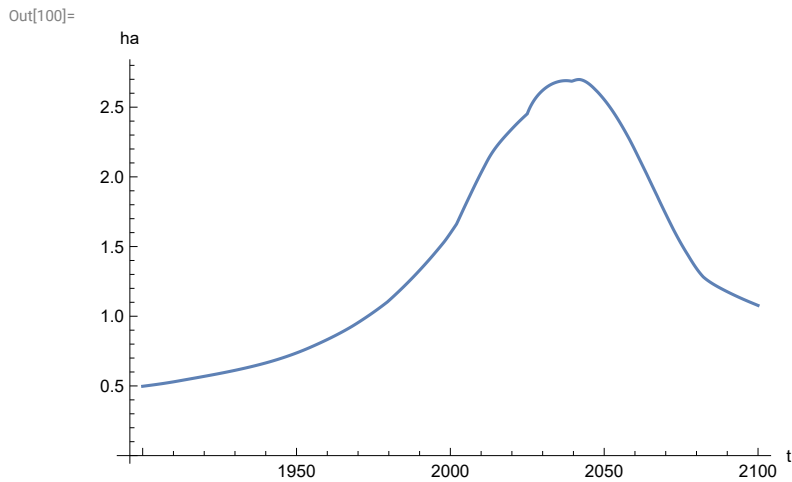
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

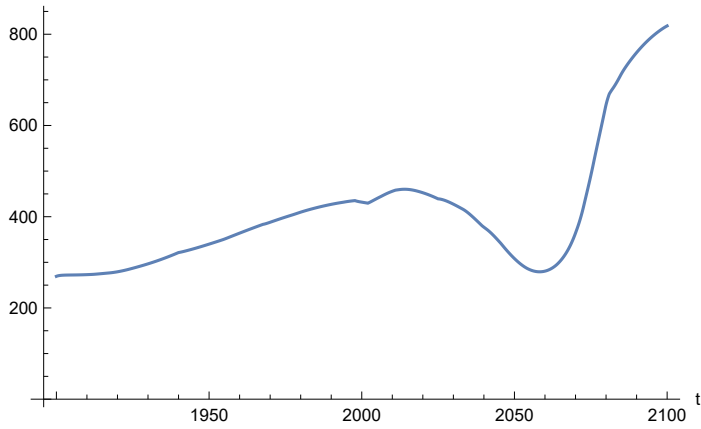


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

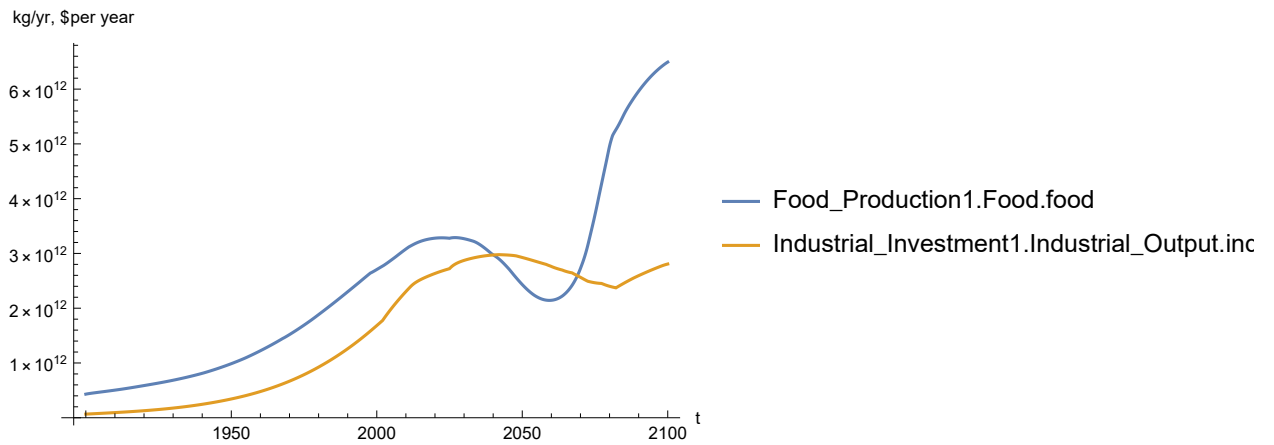


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[102]=

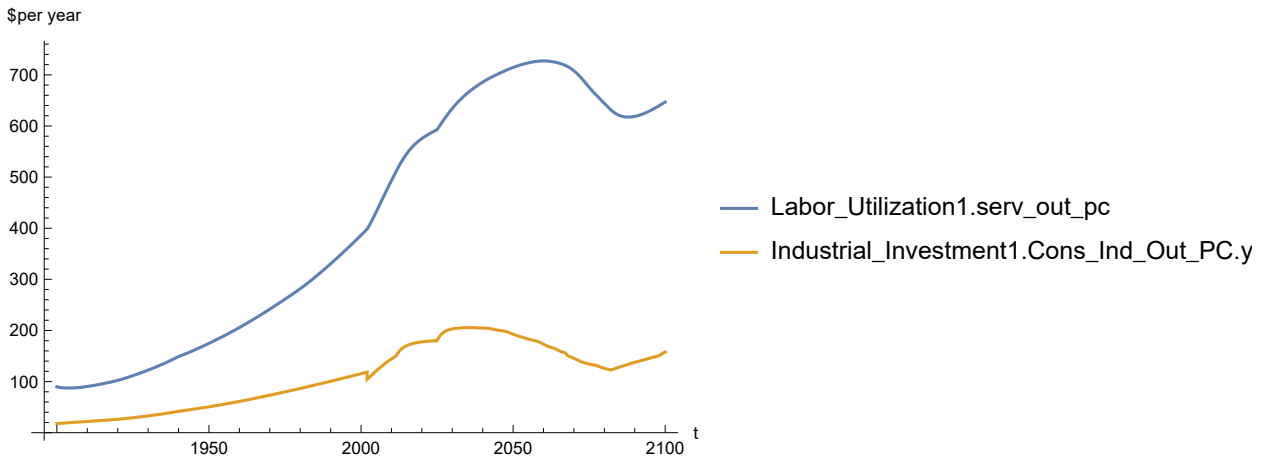


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

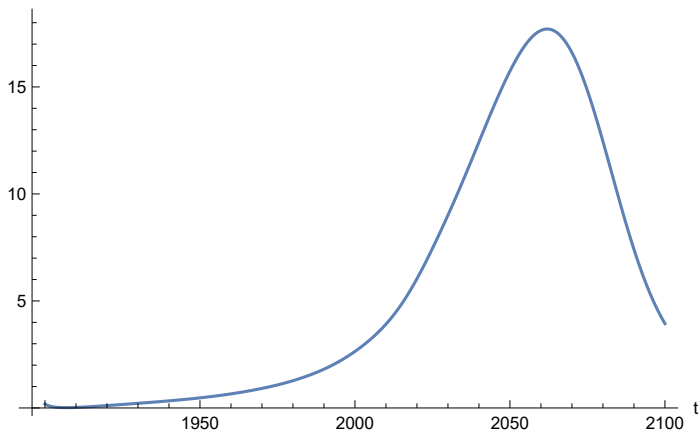
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 727.216
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 17.704

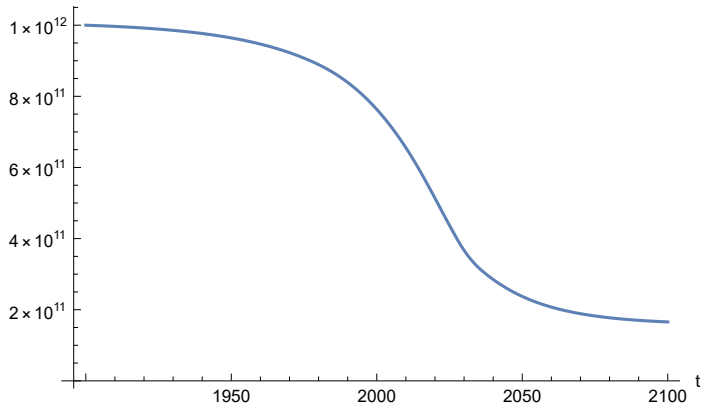
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



APPENDIX 112. BENCHMARK SCENARIO 9, Experiment 112. $LE = LE/1.03$, $t_{policy_year} = 1970$.

Last modified: 31 July 2022/0940 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

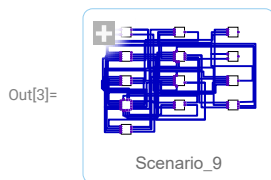
```
In[1]:= RangeData[data_] := data[[1]][4][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

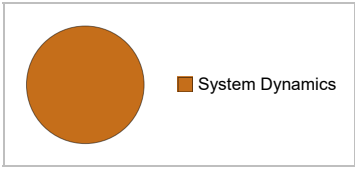
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 9.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_9"]
```



```
In[4]:= mysummary = mysim["Summary"]
```

	Model	SystemDynamics.WorldDynamics.World3.Scenario_9
	Description	Combining the measures of Scenarios #6 and #8
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

```
In[5]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]
```

```
Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}
```

```
In[6]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]
```

```
Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}
```

```
In[7]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]
```

```
Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}
```

```
In[8]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]
```

```
Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}
```

```
In[9]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]
```

```
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}
```

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

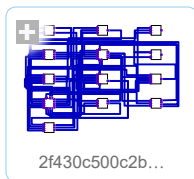
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

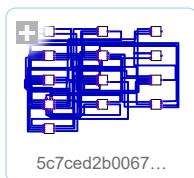
```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

Set `t_policy_year` to 1970.

```
In[20]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```


```
Out[20]=
```



Execute and plot various variables.

```
In[21]:= basesim = SystemModelSimulate[newmysim1970]
```

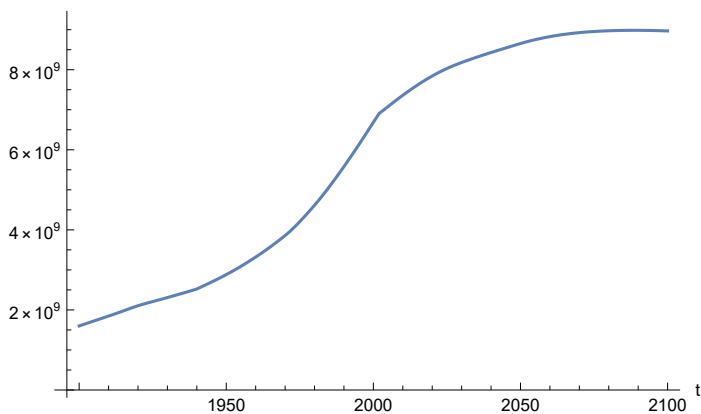
```
Out[21]=
```

```
SystemModelSimulationData [  Model: W5c7ced2b0067446fbf5e136da1d4b0c6  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[22]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

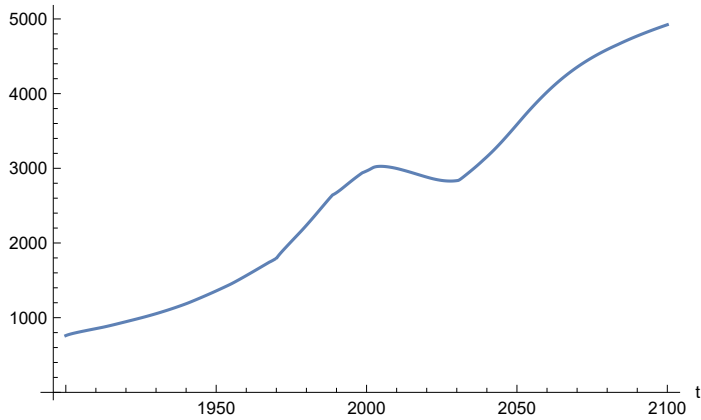
```
Out[22]=
```



Find max and min of population values.

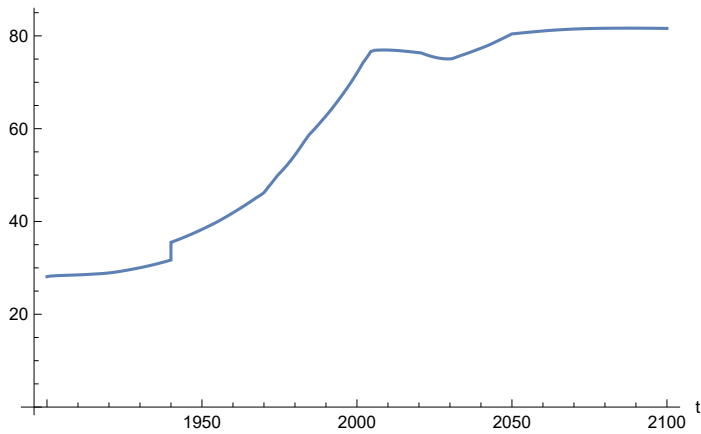
```
In[23]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $8.98378 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[24]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[24]=
```



Plot life expectancy, years.

```
In[25]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[25]=
```

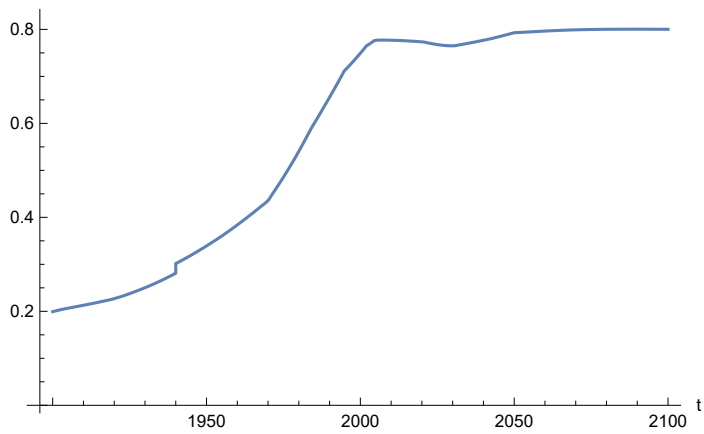


```
In[26]:=
```

Plot human welfare index.

```
In[27]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

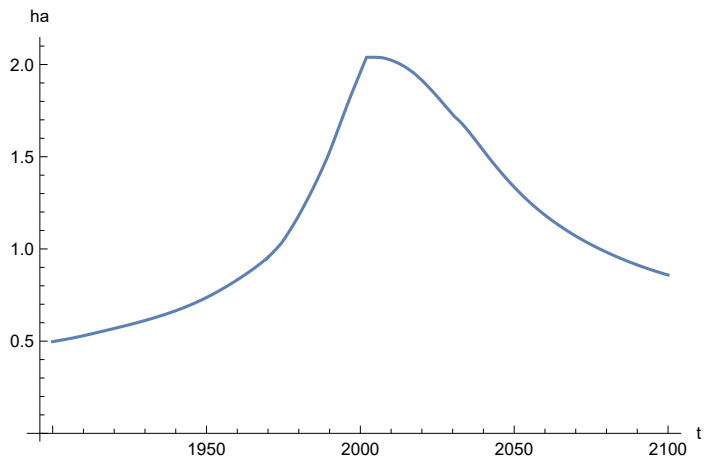
Out[27]=



Plot per capita ecological footprint, hectares.

```
In[28]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

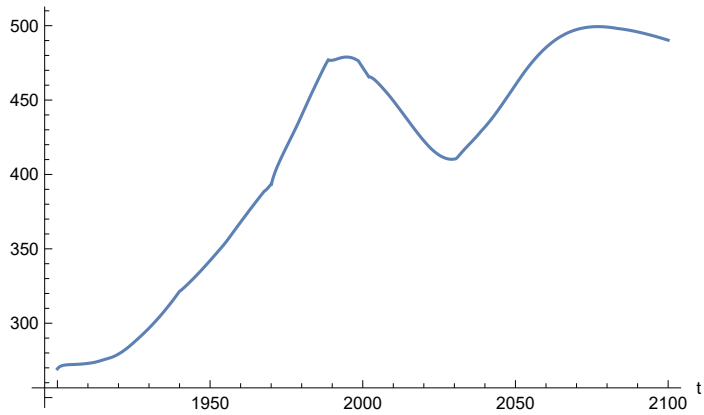
Out[28]=



Plot food production per capita (kg/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

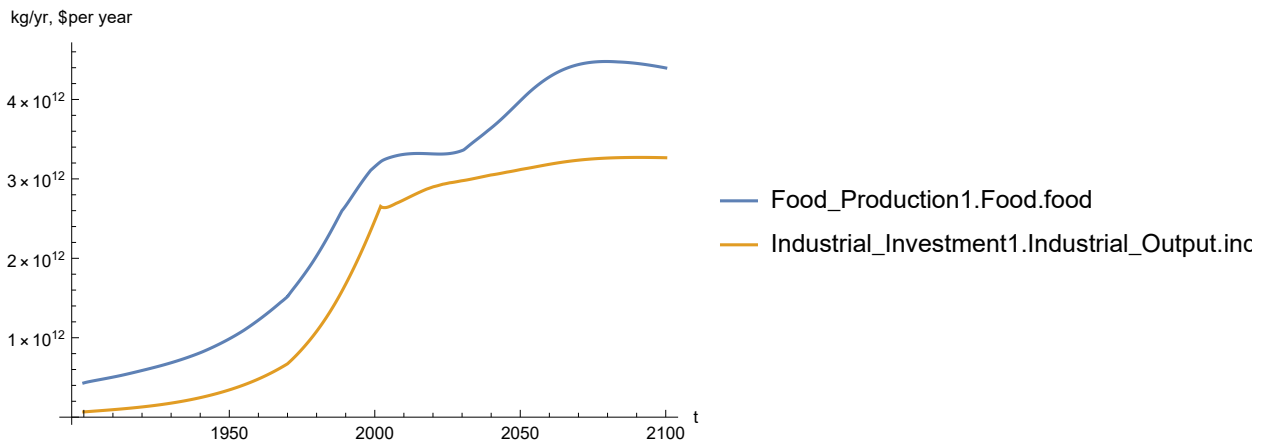
Out[29]=



Plot total food production (kg/year), and industrial output (dollars/year).

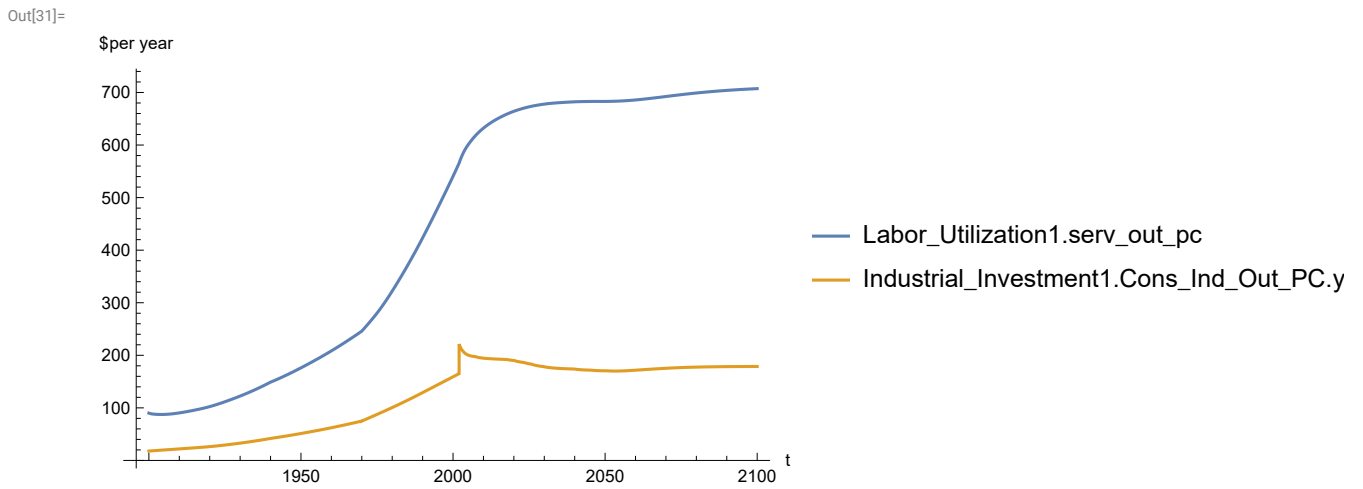
In[30]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[30]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[31]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

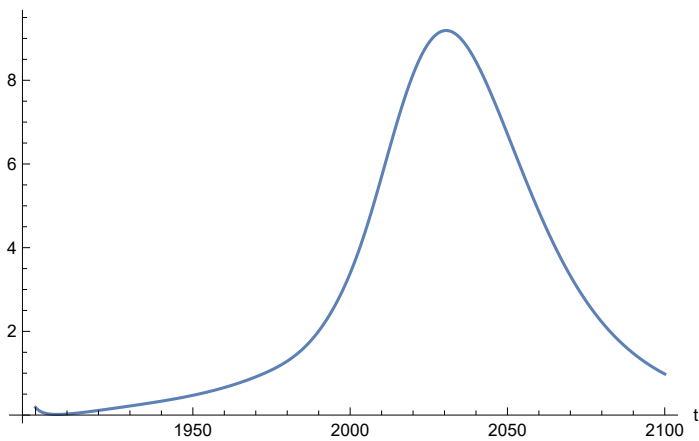


Find max and min of y values.

```
In[32]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 707.277
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[33]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[33]=
```



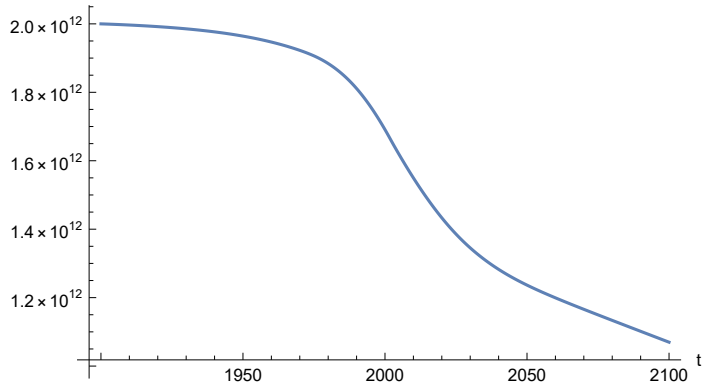
Find max and min of y values.

```
In[34]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 9.189
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[35]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[35]=

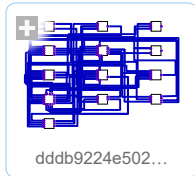


APPENDIX 113. LE/1.03, t_policy_year = 2025. Baseline Scenario 9, Experiment 113.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[36]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94, 1.94}}|>]
```

Out[36]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[42]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[42]=

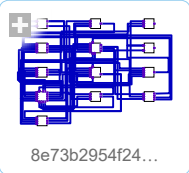
```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[43]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[43]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}


Set t_policy_year to 2025.

```
In[44]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025}|>]
```

Out[44]=  8e73b2954f24...

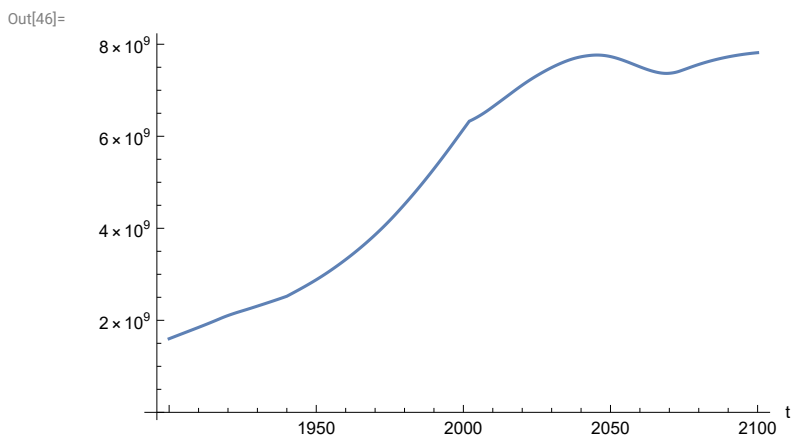
Execute and plot various variables.

```
In[45]:= basesim = SystemModelSimulate[newmysim2025]
```

Out[45]= SystemModelSimulationData [ Model: W8e73b2954f244acf9731154f846b0410
Time: 1.90×10^3 to 2.10×10^3]

Plot total population, people.

```
In[46]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

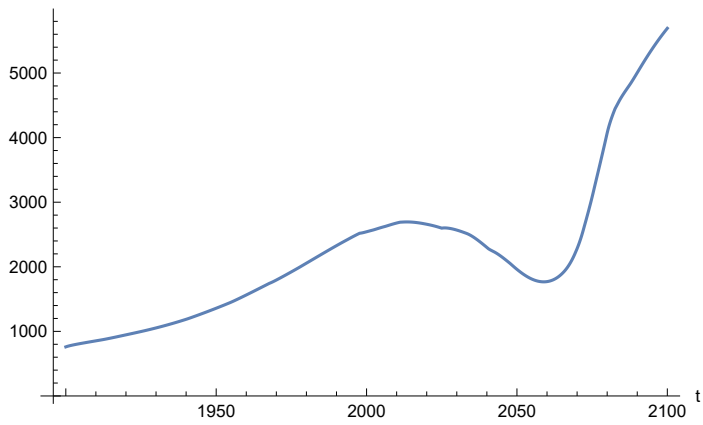
```
In[47]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

Maximum is 7.81723×10^9

Minimum is 1.6×10^9

```
In[48]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

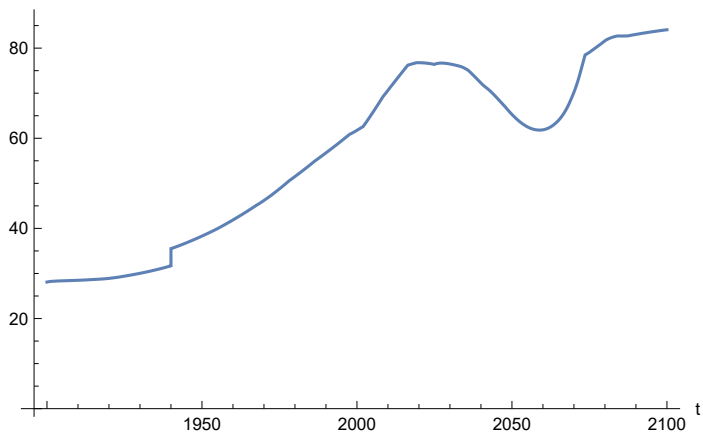
Out[48]=



Plot life expectancy, years.

```
In[49]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

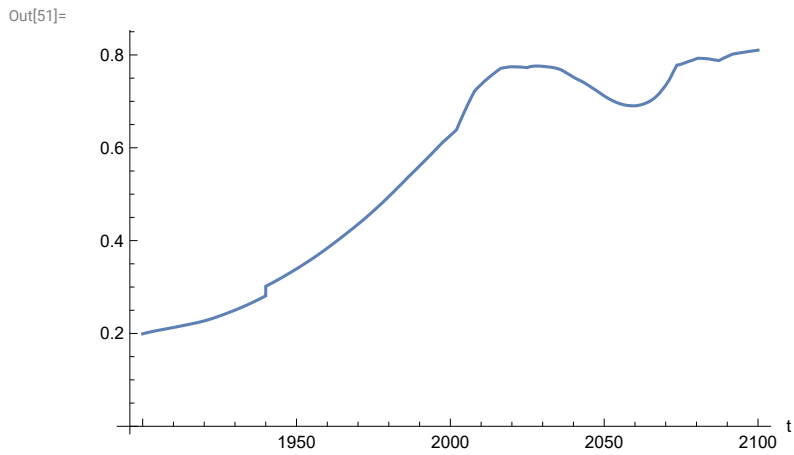
Out[49]=



In[50]:=

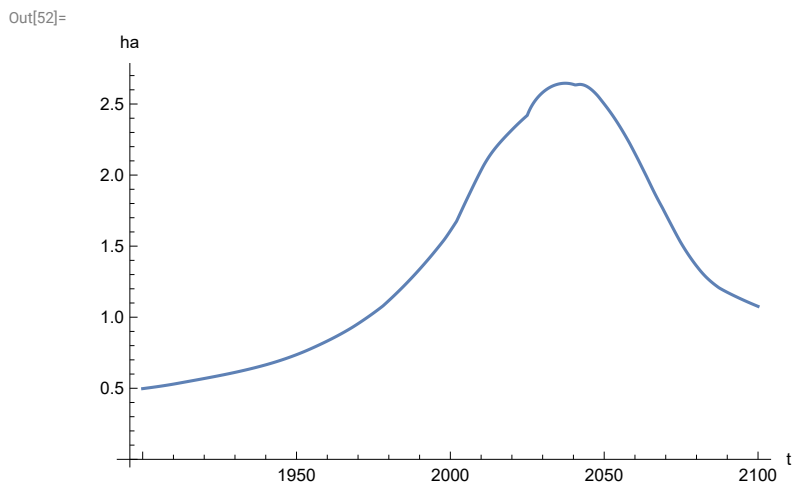
Plot human welfare index.

```
In[51]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



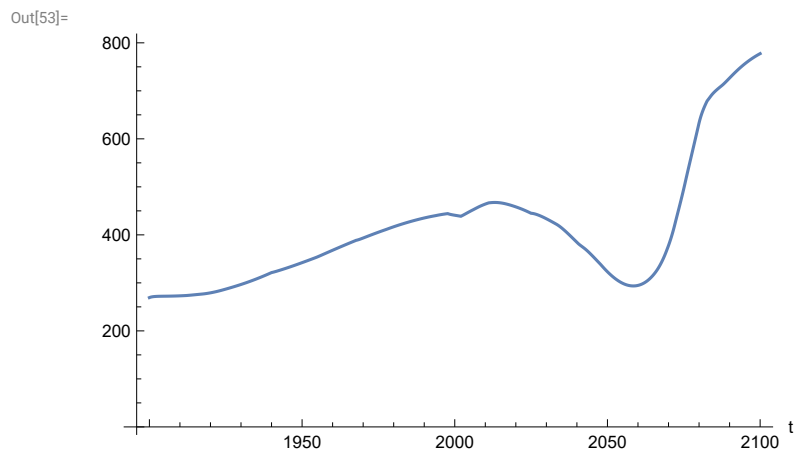
Plot per capita ecological footprint, hectares.

```
In[52]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



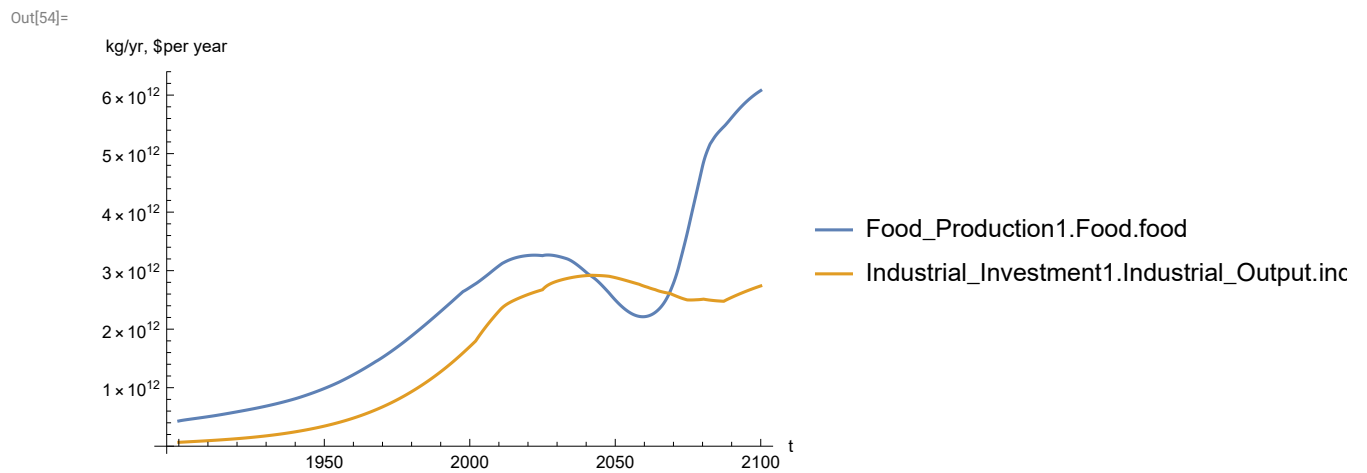
Plot food production per capita (kg/year).

In[53]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]



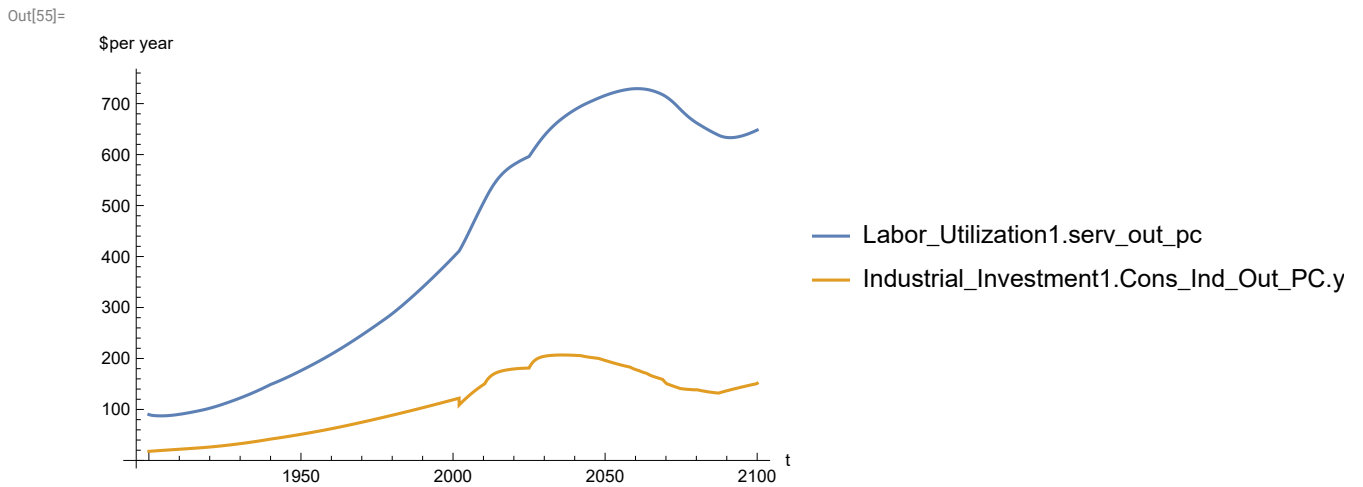
Plot total food production (kg/year), and industrial output (dollars/year).

In[54]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[55]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

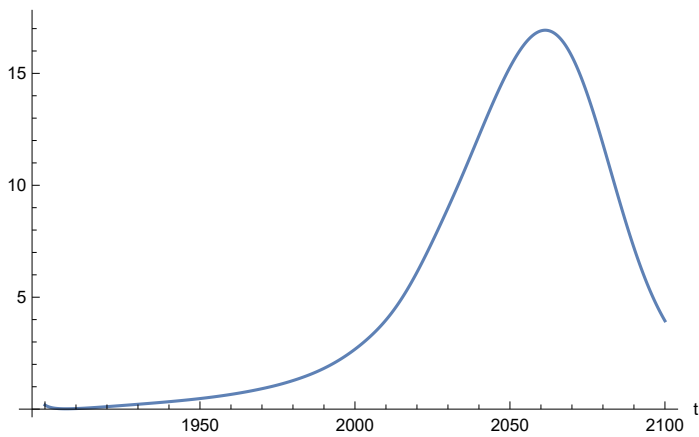


Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 729.347
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[57]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[57]=
```



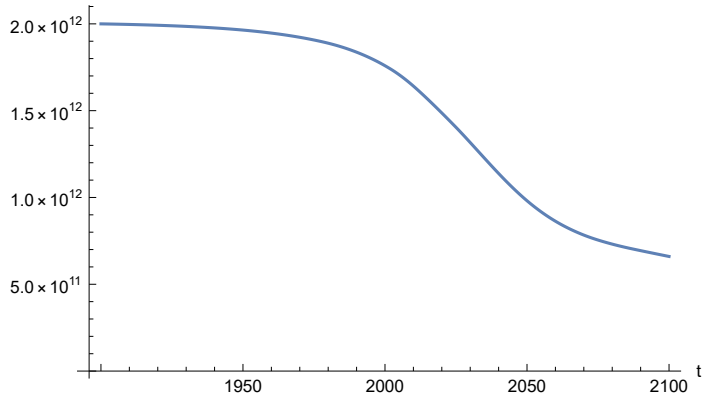
Find max and min of y values.

```
In[58]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 16.9282
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[59]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[59]=

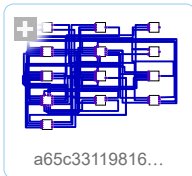


APPENDIX 114. LE/1.05, t_policy_year = 1970. Baseline Scenario 9, Experiment 114.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[60]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[60]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[61]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[61]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[62]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[62]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[63]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[63]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[64]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[64]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[65]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[65]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[66]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[66]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

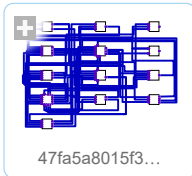
```
In[67]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[67]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 1970.

```
In[68]:= newmysim1970 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 1970}} >]
```

```
Out[68]=
```



Execute and plot various variables.

```
In[69]:= basesim = SystemModelSimulate[newmysim1970]
```

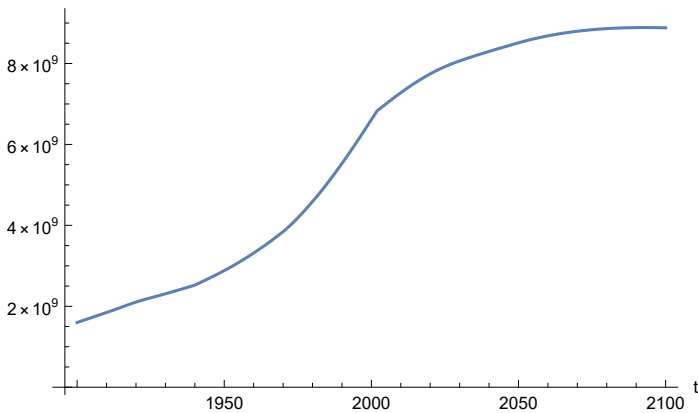
```
Out[69]=
```

```
SystemModelSimulationData [  Model: W47fa5a8015f34e8cabb64e08dd7d9b7c  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[70]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[70]=
```



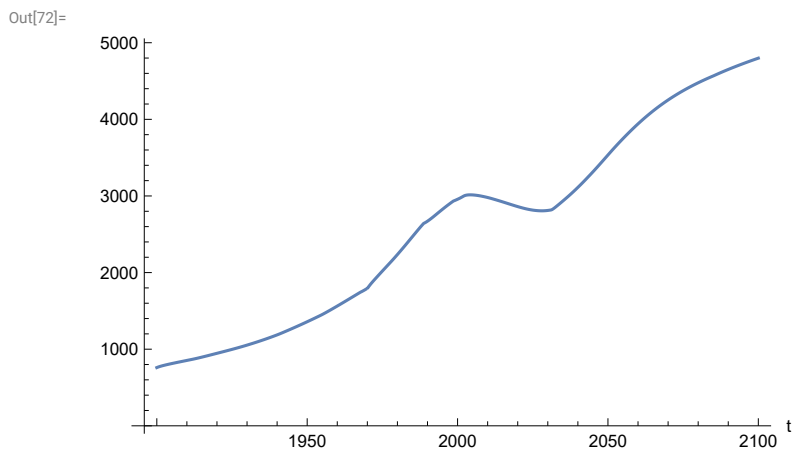
Find max and min of population values.

```
In[71]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.88828 \times 10^9$ 
```

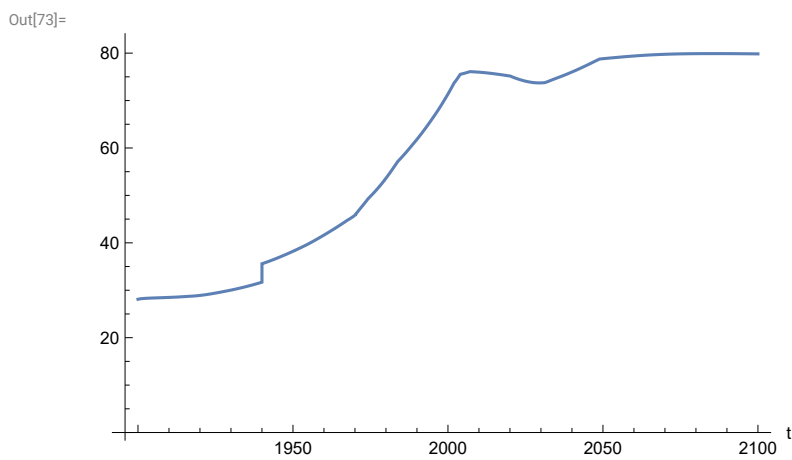
```
Minimum is  $1.6 \times 10^9$ 
```

In[72]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]



Plot life expectancy, years.

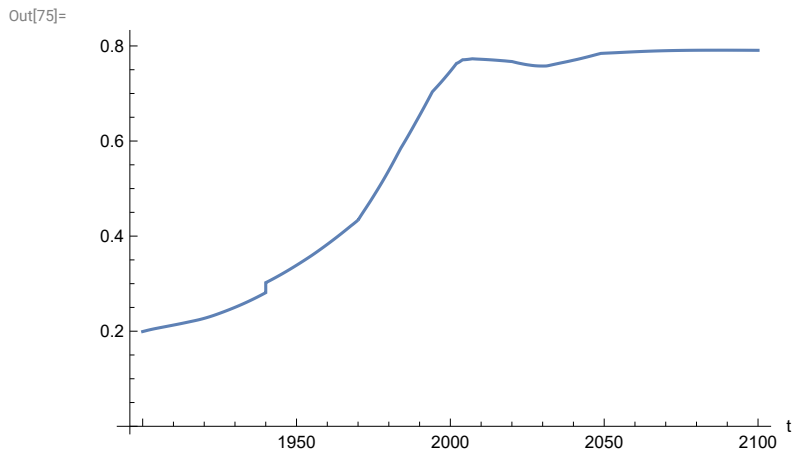
In[73]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]



In[74]:=

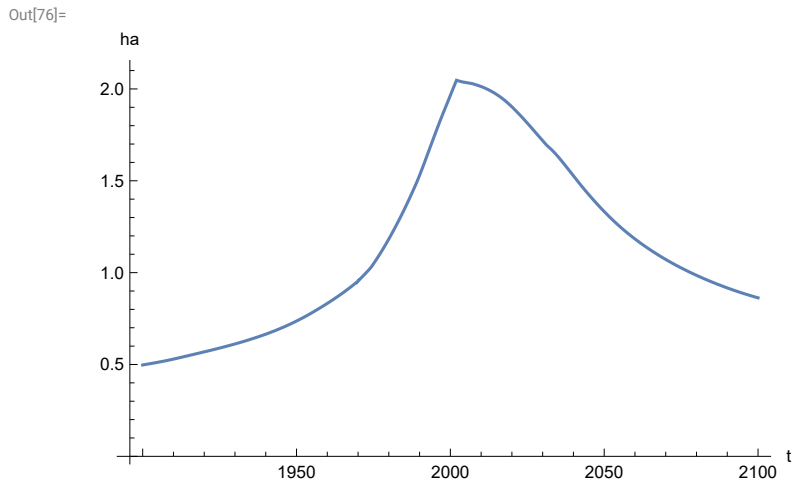
Plot human welfare index.

```
In[75]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

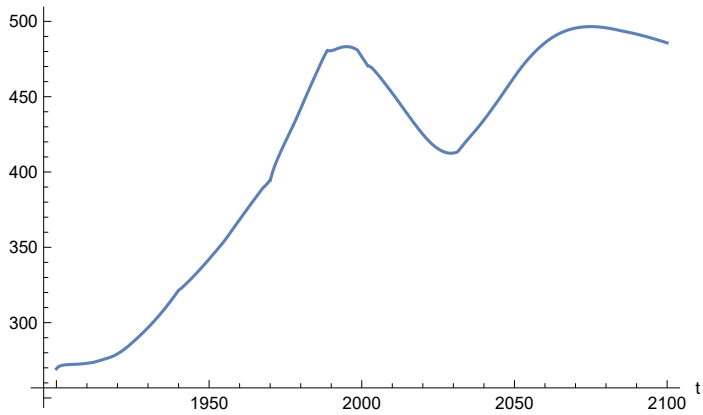
```
In[76]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[77]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

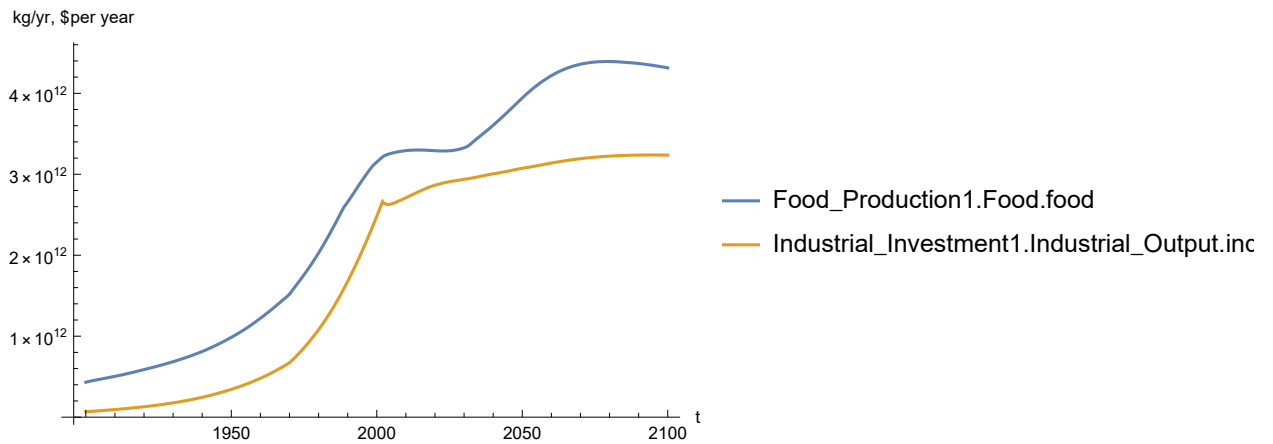
Out[77]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[78]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

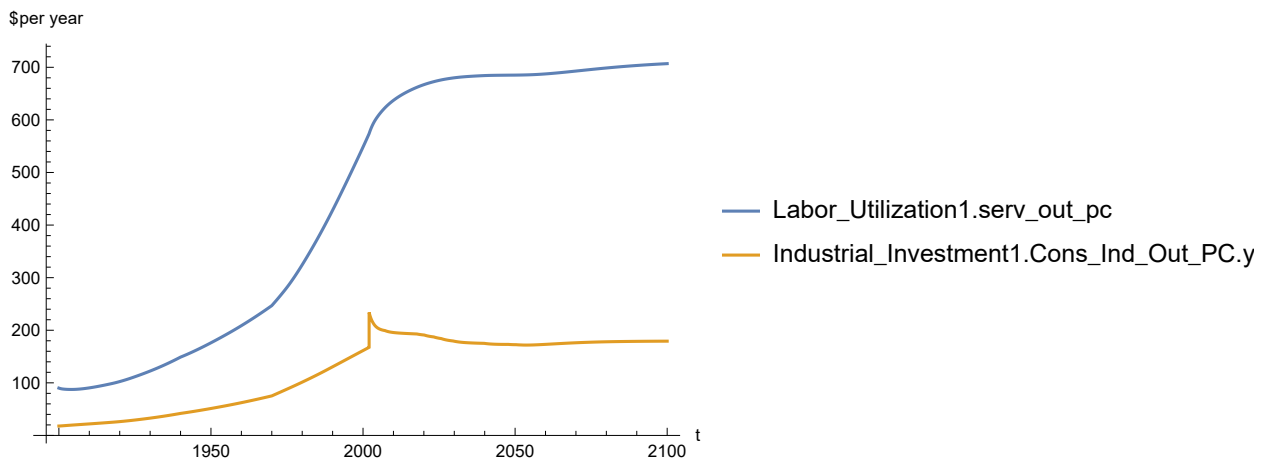
Out[78]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[79]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[79]=



Find max and min of y values.

```
In[80]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

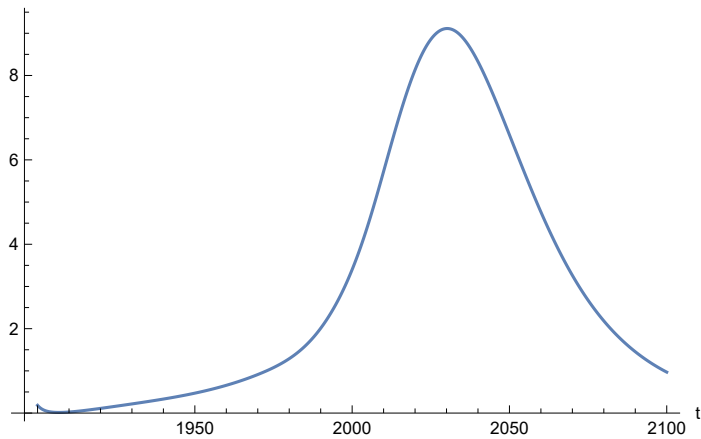
Maximum is 706.941

Minimum is 87.4451

Plot persistent pollution index.

```
In[81]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[81]=



Find max and min of y values.

```
In[82]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

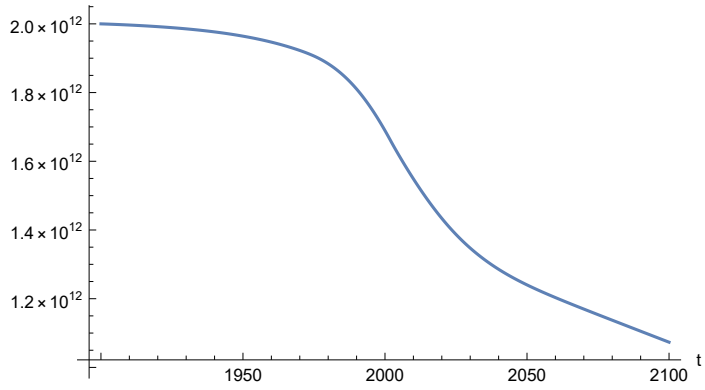
Maximum is 9.11273

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[83]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

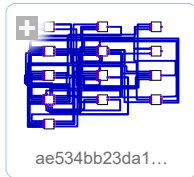
Out[83]=



APPENDIX 115. Baseline Scenario 9, Experiment 115. LE = LE/1.05, t_policity_year = 2025.

```
In[84]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.95, 1.42, 1.81, 1.90, 1.90, 1.90, 1.90}}|>]
```

Out[84]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[85]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[85]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.95}
```

```
In[86]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[86]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[87]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[87]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[88]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[88]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[89]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[89]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[90]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[90]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```

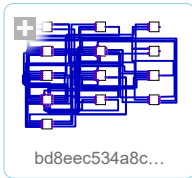
```
In[91]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

Out[91]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Set `t_policy_year` to 2025.

```
In[92]:= newmysim2025 = SystemModel[strsim, <{"ParameterValues" → {"t_policy_year" → 2025}} >]
Out[92]=
```



Execute and plot various variables.

```
In[93]:= basesim = SystemModelSimulate[newmysim2025]
```

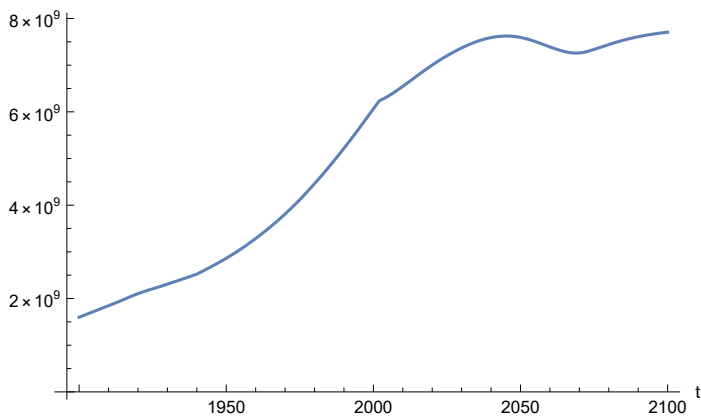
```
Out[93]=
```

```
SystemModelSimulationData [ { Model: Wbd8eec534a8c46bca389cc935d545c08
Time: 1.90 × 103 to 2.10 × 103 }
```

Plot total population, people.

```
In[94]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[94]=
```



Find max and min of population values.

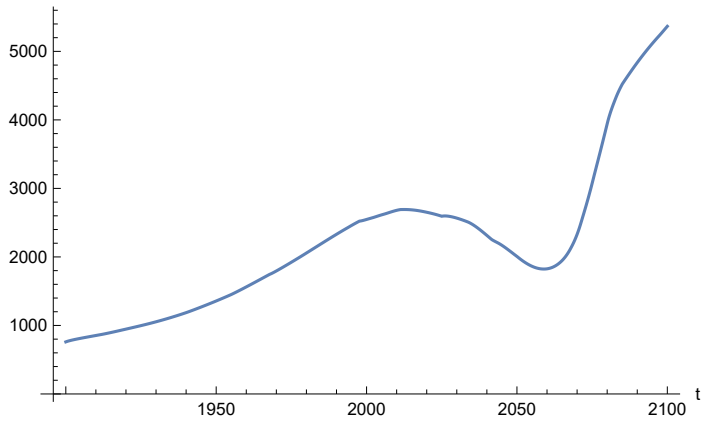
```
In[95]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 7.70567 × 109
```

```
Minimum is 1.6 × 109
```

```
In[96]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

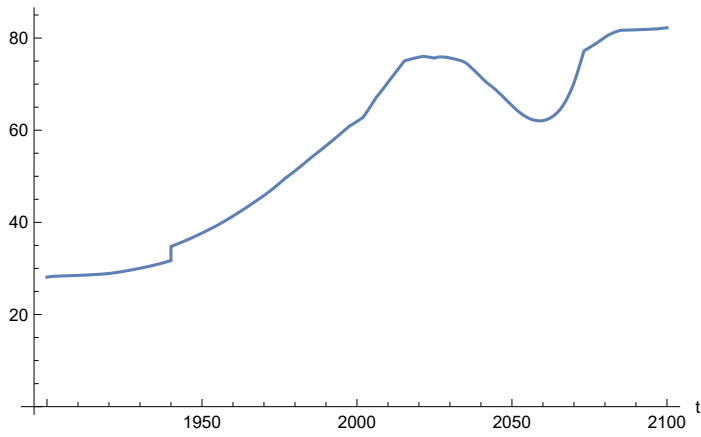
Out[96]=



Plot life expectancy, years.

```
In[97]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

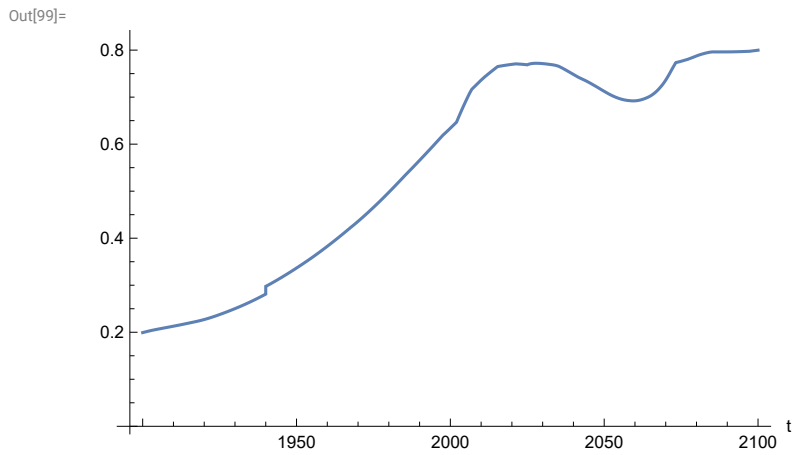
Out[97]=



In[98]:=

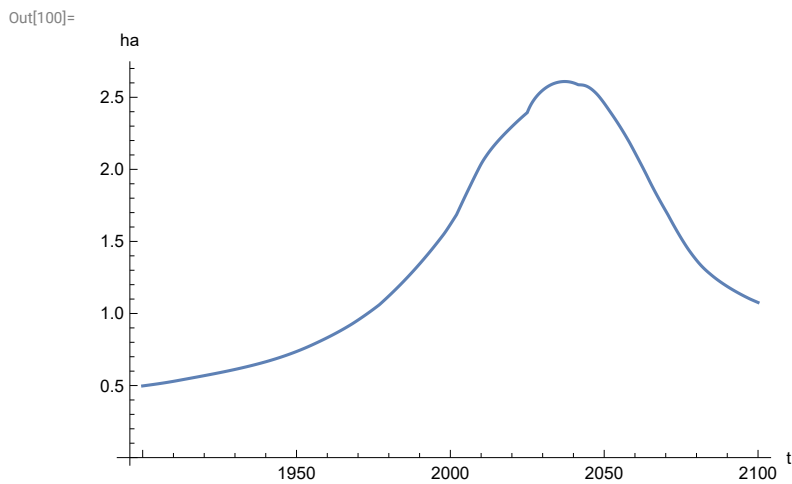
Plot human welfare index.

```
In[99]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

```
In[100]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

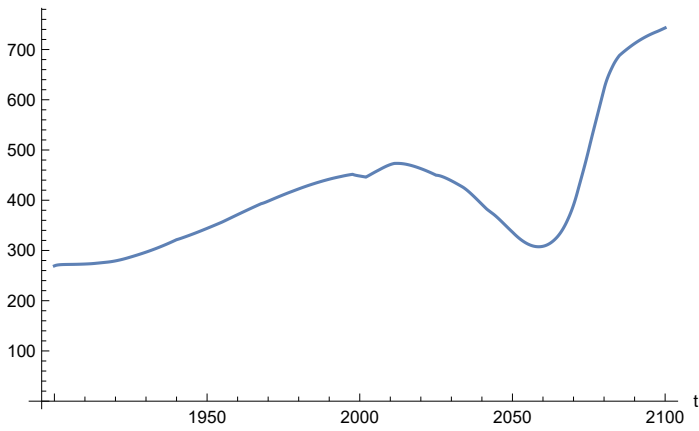


Plot food production per capita (kg/year).

In[101]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

Out[101]=

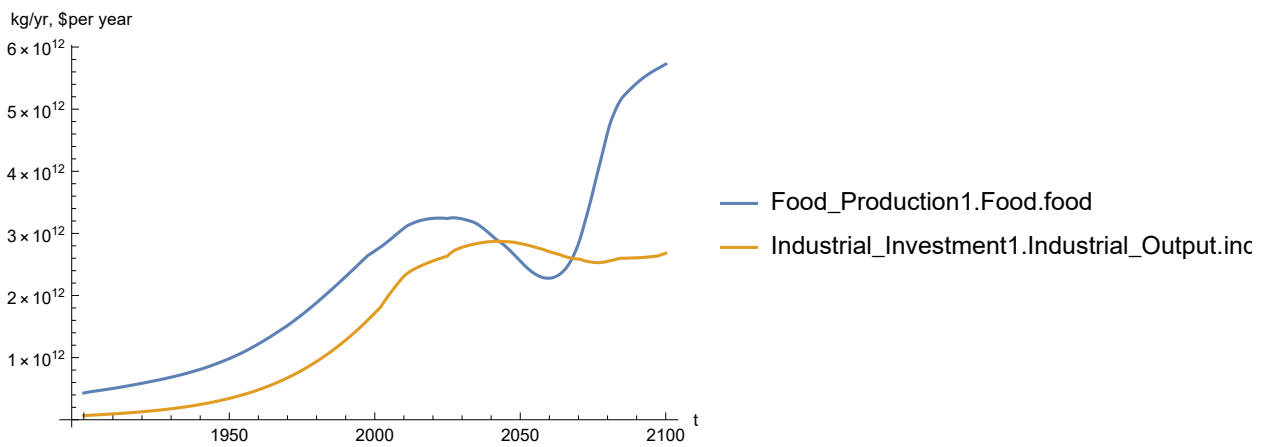


Plot total food production (kg/year), and industrial output (dollars/year).

In[102]:=

```
SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.inc"}]
```

Out[102]=

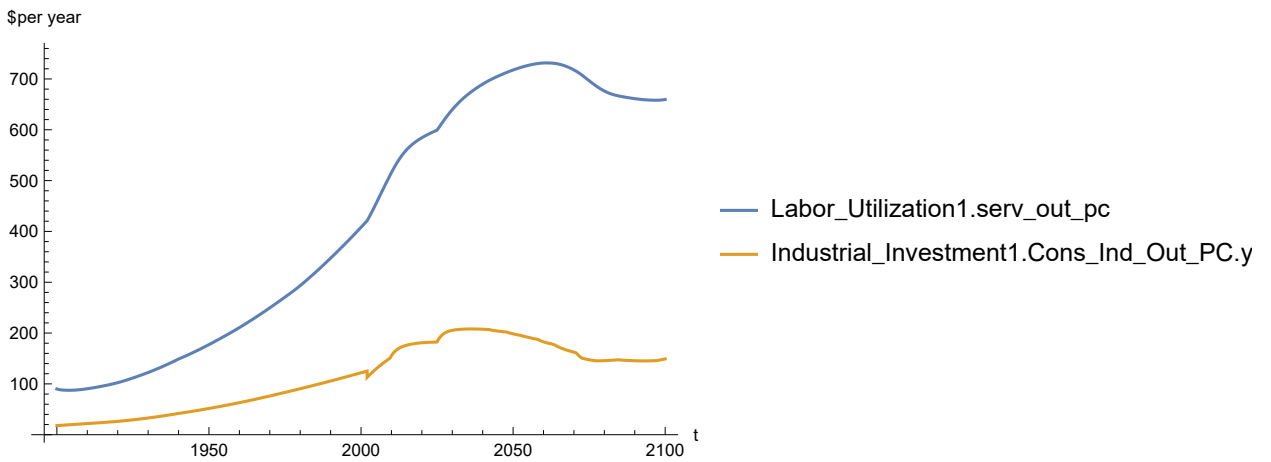


Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

In[103]:=

```
SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[103]:=



Find max and min of y values.

In[104]:=

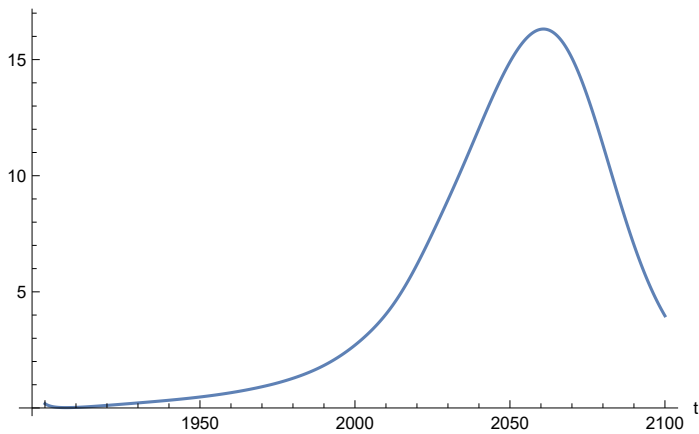
```
MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 731.534
Minimum is 87.4451
```

Plot persistent pollution index.

In[105]:=

```
SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[105]:=



Find max and min of y values.

In[106]:=

```
MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 16.3161

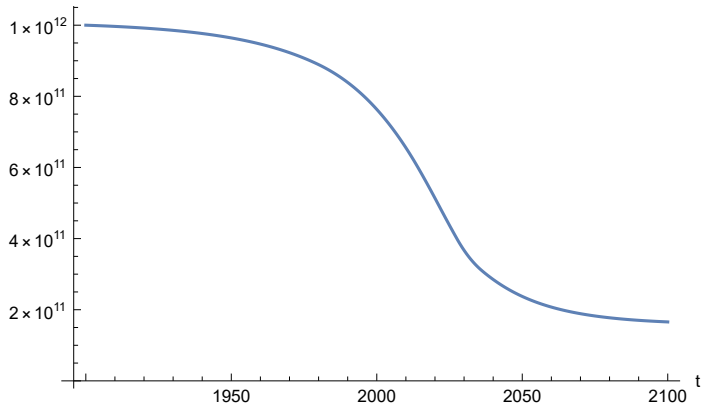
Minimum is 0.0150765

Plot non-renewable resources remaining.

In[107]:=

```
SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[]:=



APPENDIX 116. BENCHMARK SCENARIO 9, Experiment 116. LE = LE/1.1, t_policy_year = 1970.

Last modified: 31 July 2022/1005 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e., not piecewise) defined.) The function does not check for errors.

```
In[ ]:= RangeData[data_] := data[[1]][[4]][[3]];
```

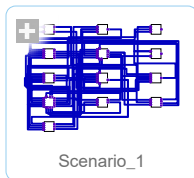
Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

```
In[ ]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
  Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 9.

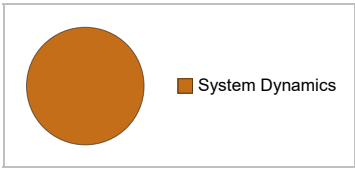
```
mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_9"]
```

Out[]:=



In[]:= **mysummary = mysim["Summary"]**

Out[]:=

Model	SystemDynamics.WorldDynamics.World3.Scenario_1
Description	Original WORLD3 model
Simulation Interval	True
Plot	0
Control Center	106
Background Color	True
Symbol	265
Symbol	265
Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[]:=
 {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[]:=
 {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[]:=
 {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[]:=
 {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

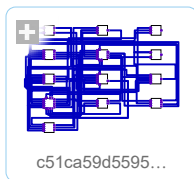
Out[]:=
 {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[ ]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[ ]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[ ]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
Out[ ]:=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[ ]:=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

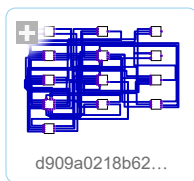
```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

```
In[ ]:= newmysim1970 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 1970}|>]
```

```
Out[ ]:=
```



Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim1970]
```

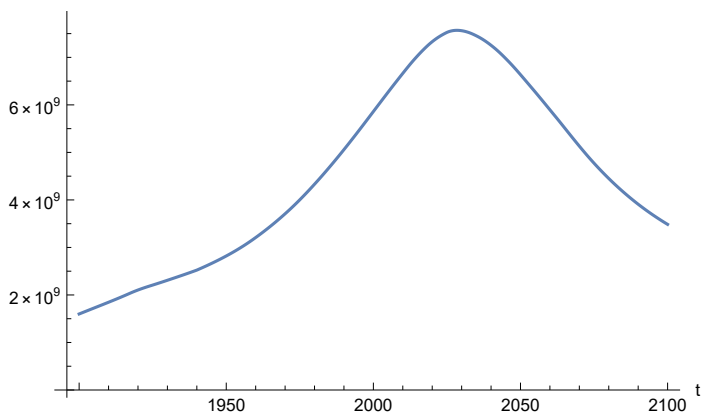
```
Out[ ]:=
```

```
SystemModelSimulationData [
  Model: Wd909a0218b624fa2848802cb18395bb8
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$ 
]
```

Plot total population, people.

```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

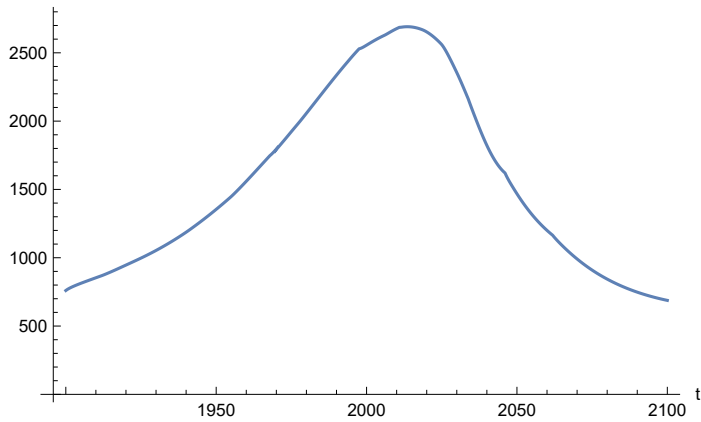
```
Out[ ]:=
```



Find max and min of population values.

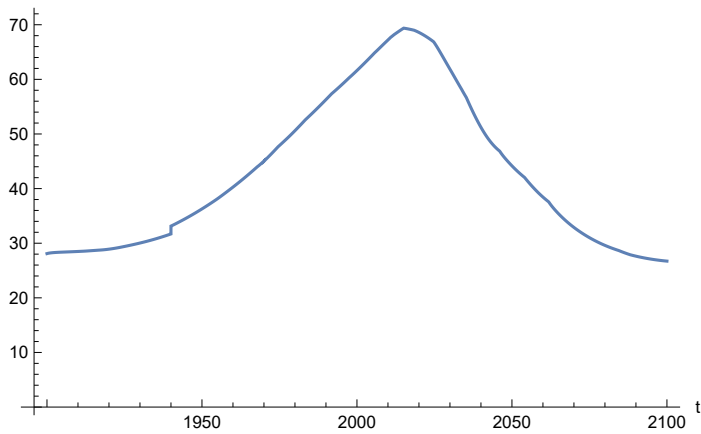
```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
Maximum is  $7.56904 \times 10^9$ 
Minimum is  $1.6 \times 10^9$ 
```

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
Out[ ]:=
```



Plot life expectancy, years.

```
In[ ]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
Out[ ]:=
```

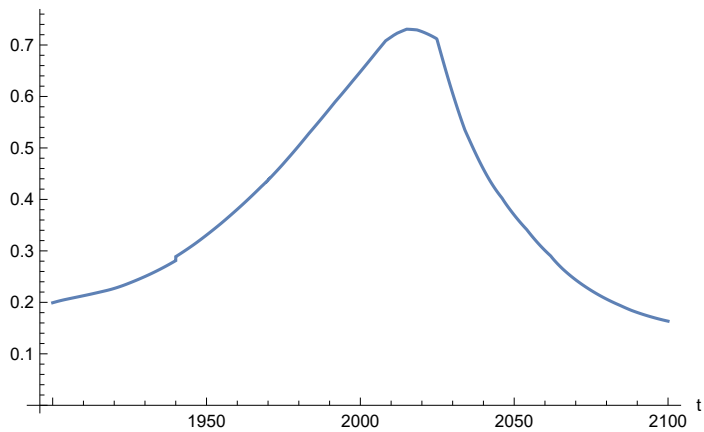


```
In[ ]:=
```

Plot human welfare index.

```
In[ ]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```

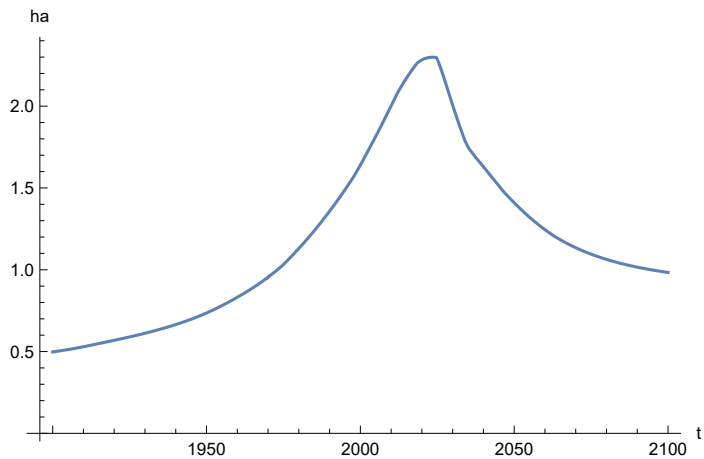
Out[]:=



Plot per capita ecological footprint, hectares.

```
In[ ]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```

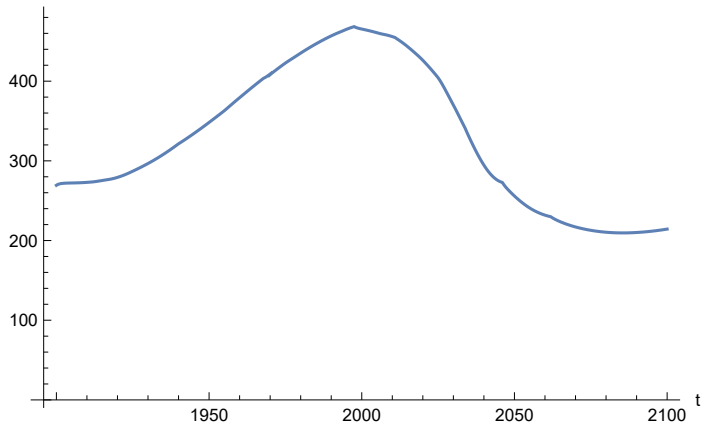
Out[]:=



Plot food production per capita (kg/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

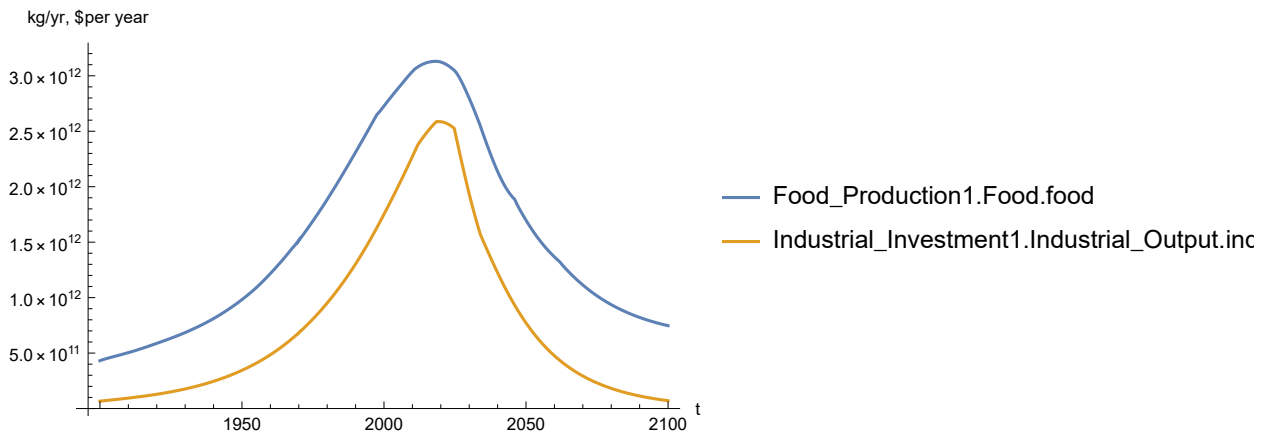
Out[]:=



Plot total food production (kg/year), and industrial output (dollars/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
    "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

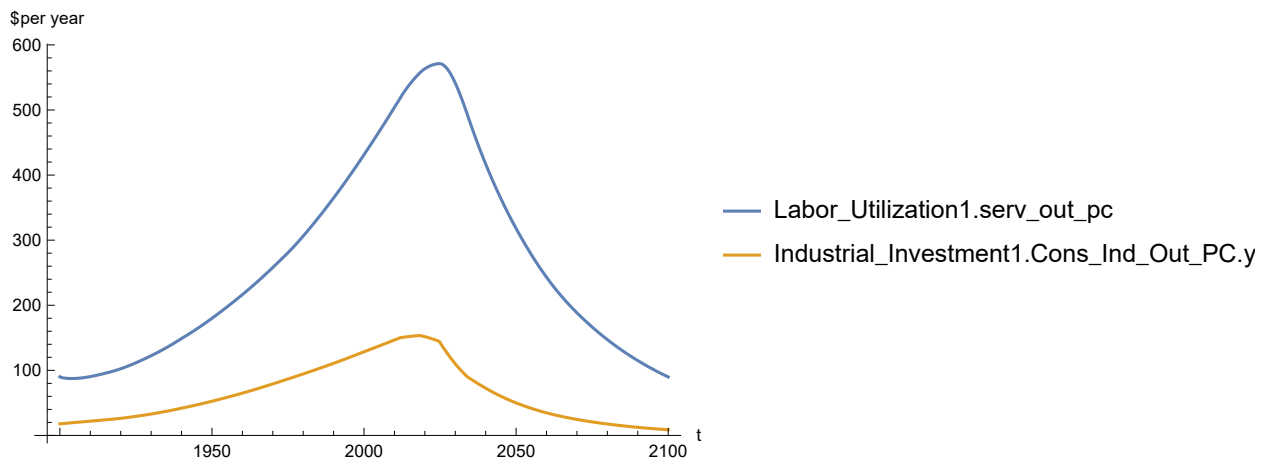
Out[]:=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[*]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[*]=



Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

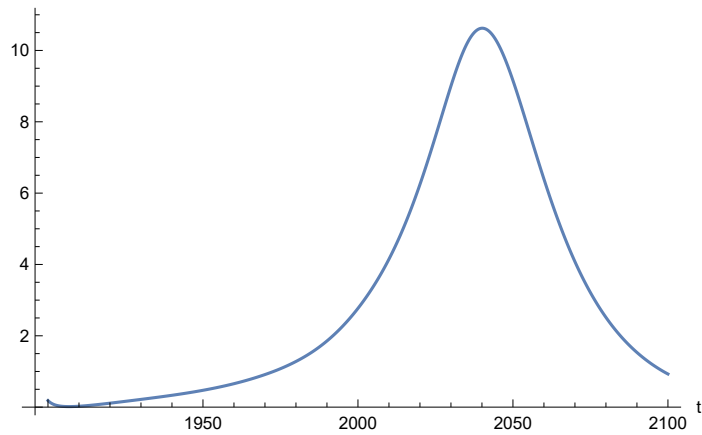
Maximum is 571.174

Minimum is 87.4451

Plot persistent pollution index.

```
In[*]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[*]=



Find max and min of y values.

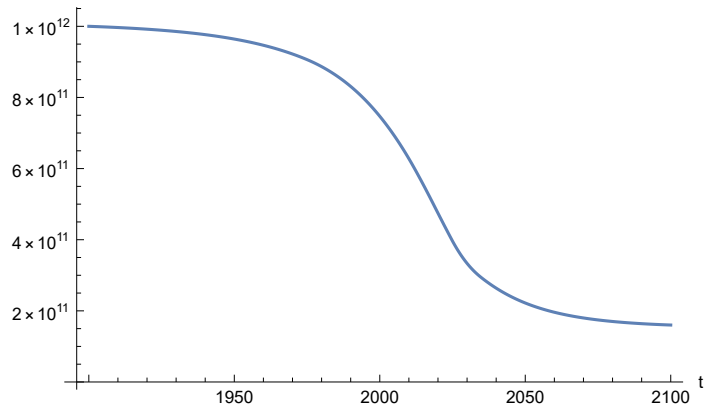
```
In[*]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

Maximum is 10.6234

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[*]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[*]=
```

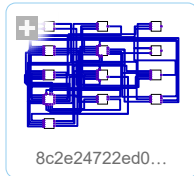


APPENDIX 117. LE/1.1, t_policy_year = 2025. Baseline Scenario 9, Experiment 117.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[ ]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

Out[]:=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[ ]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[]:=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

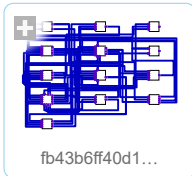
```
In[ ]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[ ]:= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set t_policy_year to 2025.

```
In[ ]:= newmysim2025 = SystemModel[strsim, <|"ParameterValues" → {"t_policy_year" → 2025} |>]
```


```
Out[ ]:=
```



Execute and plot various variables.

```
In[ ]:= basesim = SystemModelSimulate[newmysim2025]
```

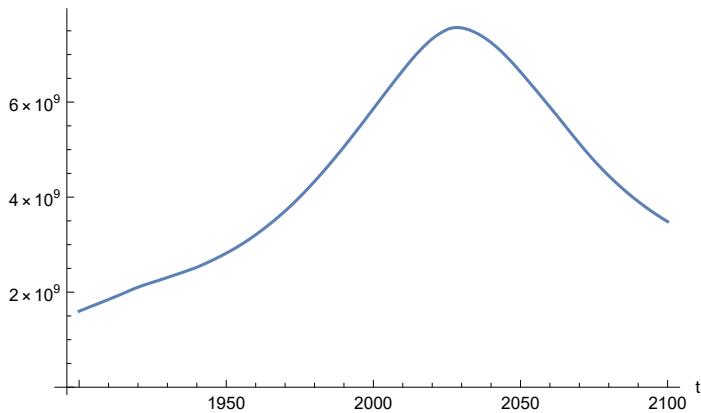
```
Out[ ]:=
```

```
SystemModelSimulationData [ {  Model: Wfb43b6ff40d14911899f4714a140b6f1
  Time: 1.90 × 103 to 2.10 × 103 } ]
```

Plot total population, people.

```
In[ ]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[ ]:=
```



Find max and min of population values.

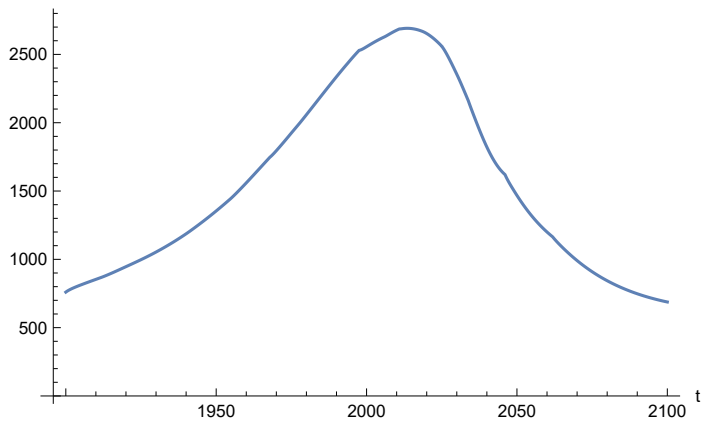
```
In[ ]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 7.56895 × 109
```

```
Minimum is 1.6 × 109
```

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

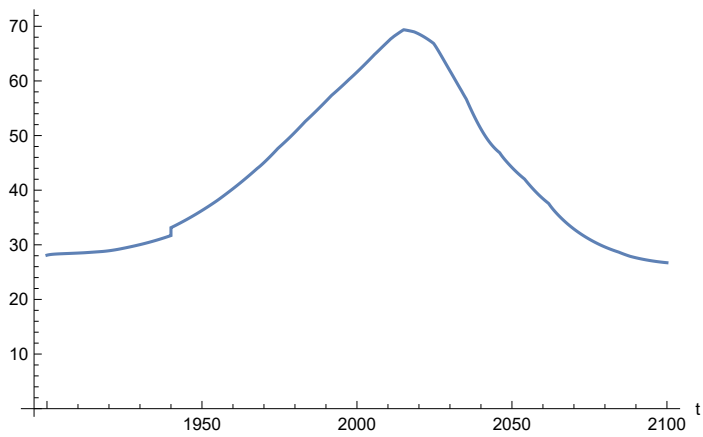
Out[]:=



Plot life expectancy, years.

```
In[ ]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

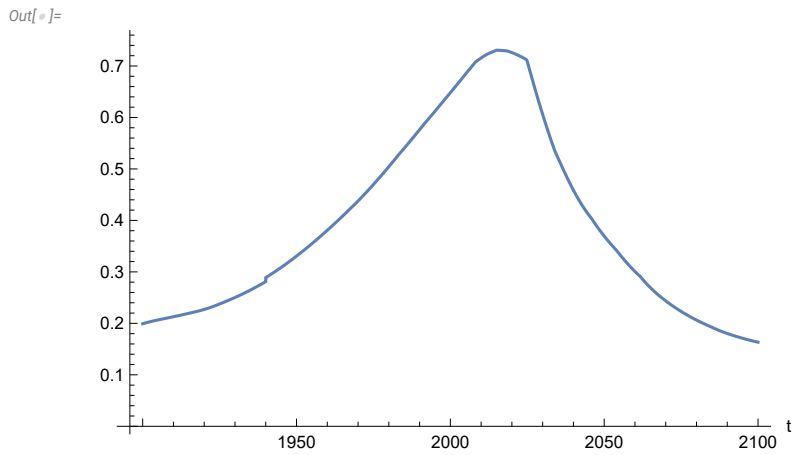
Out[]:=



In[]:=

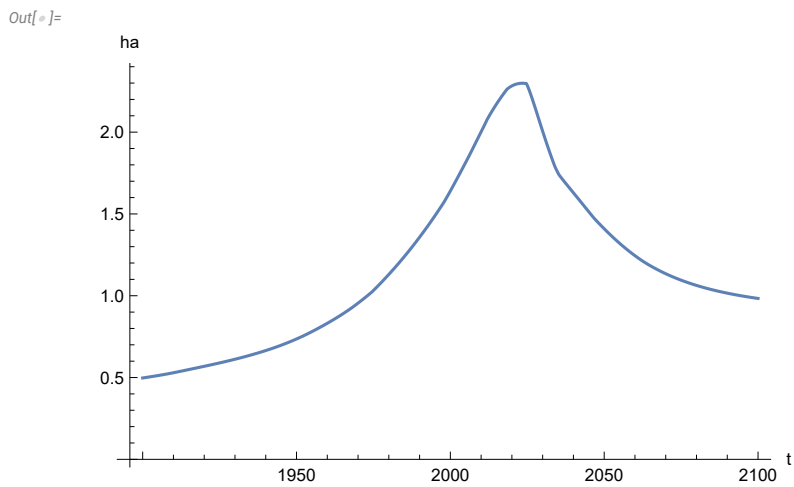
Plot human welfare index.

```
In[ ]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

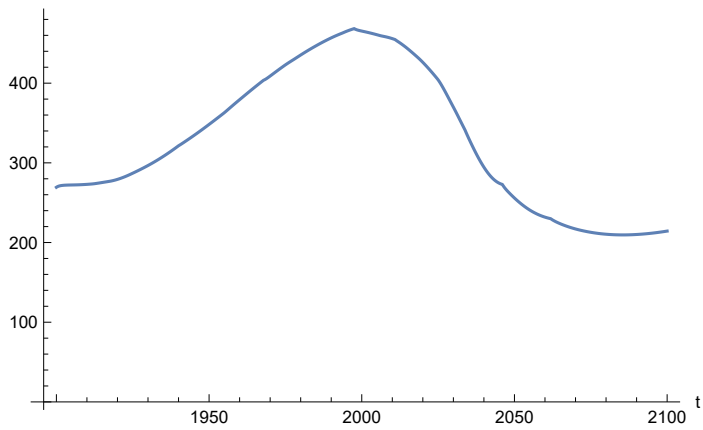
```
In[ ]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]
```

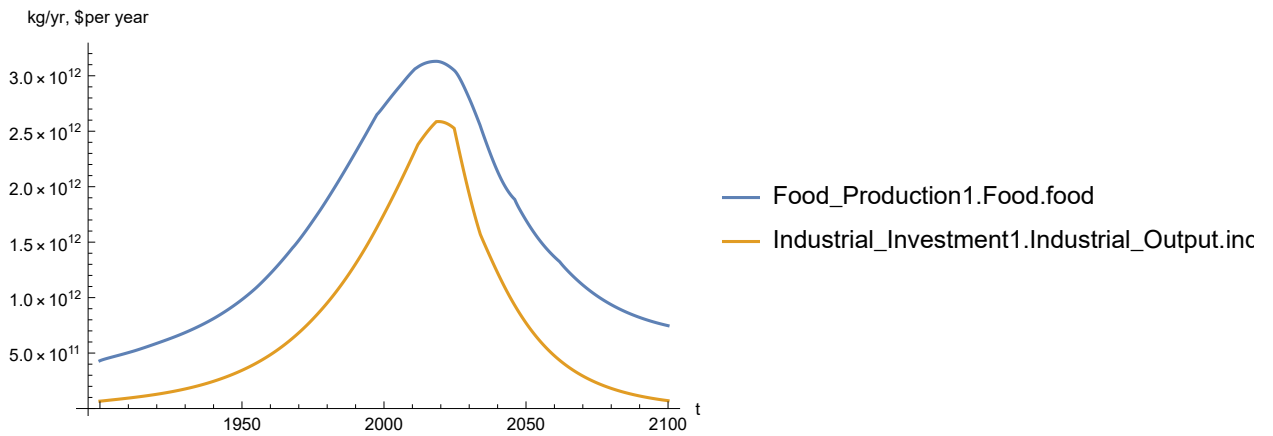
Out[]:=



Plot total food production (kg/year), and industrial output (dollars/year).

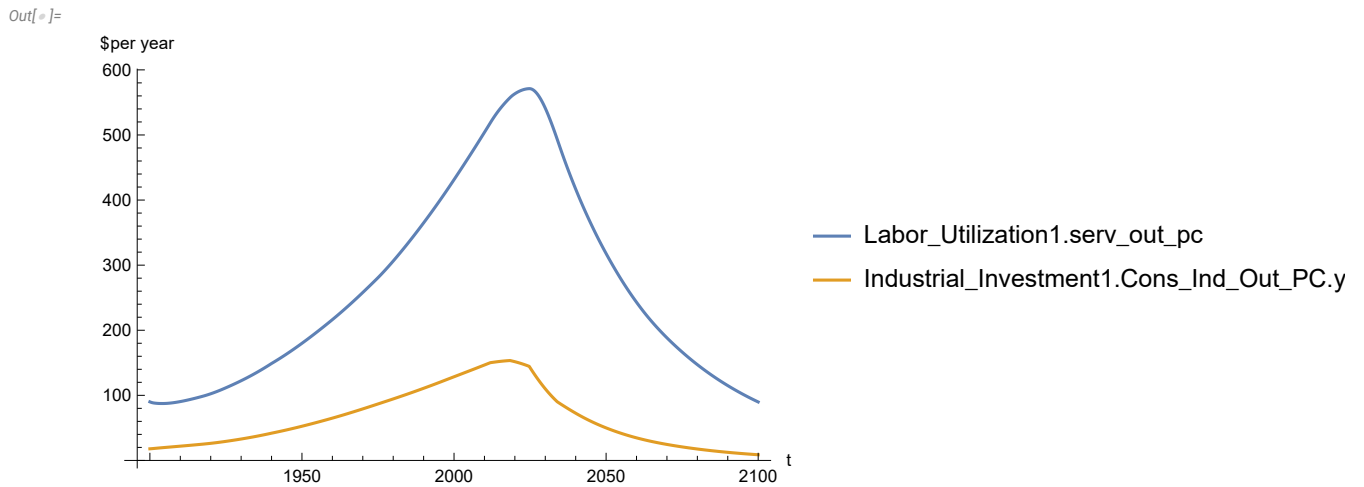
```
In[ ]:= SystemModelPlot[basesim, {"Food_Production1.Food.food",
  "Industrial_Investment1.Industrial_Output.industrial_output"}]
```

Out[]:=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[*]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

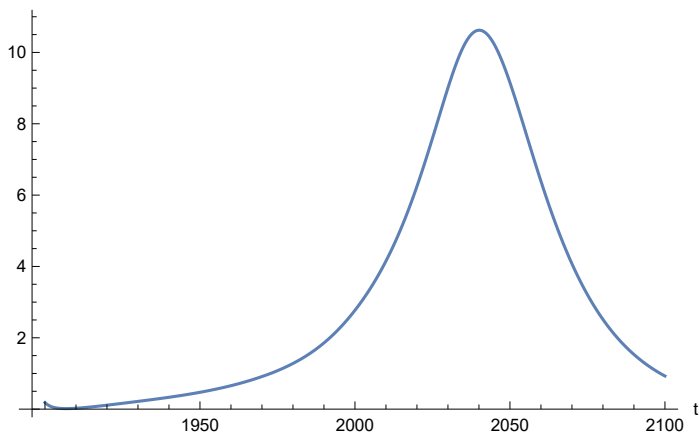


Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 571.152
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[*]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[*]=
```

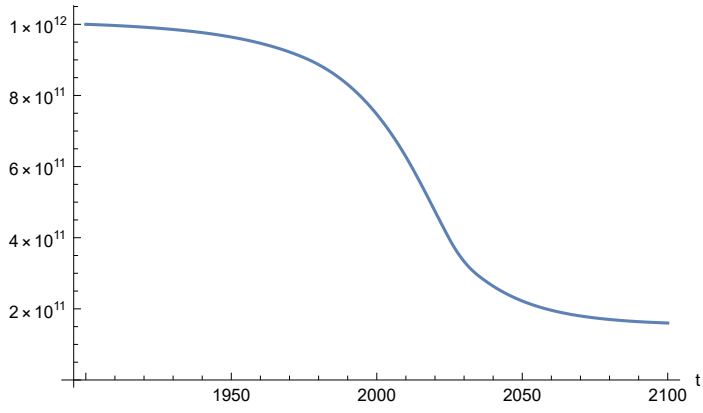


Find max and min of y values.

```
In[*]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.6227
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[*]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[*]=
```



APPENDIX 9A1. BENCHMARK SCENARIO 8, Experiment 9A1. $LE = LE/1.001$, $t_policy_year = 2002$.

Last modified: 31 July 2022/1210 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

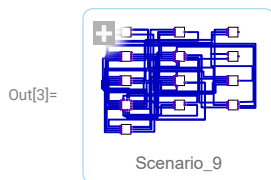
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

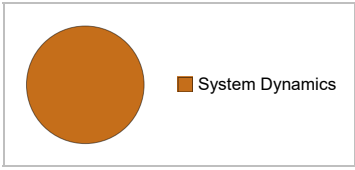
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 9.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_9"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_9
	D	Combining the measures of Scenarios #6 and #8
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

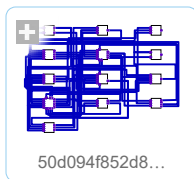
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.001. Note: this particular divisor does not change the two-significant-figure Serv_2.y_vals

```
In[12]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {1.0, 1.5, 1.9, 2.0, 2.0, 2.0, 2.0}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 1}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.5}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.9}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 2}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 2}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 2}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 2}
```

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

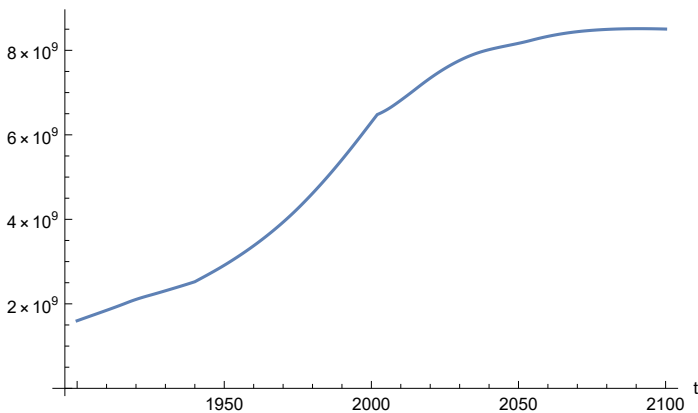
```
Out[20]=
```

```
SystemModelSimulationData [  Model: W50d094f852d84feabf20a59804aff627  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

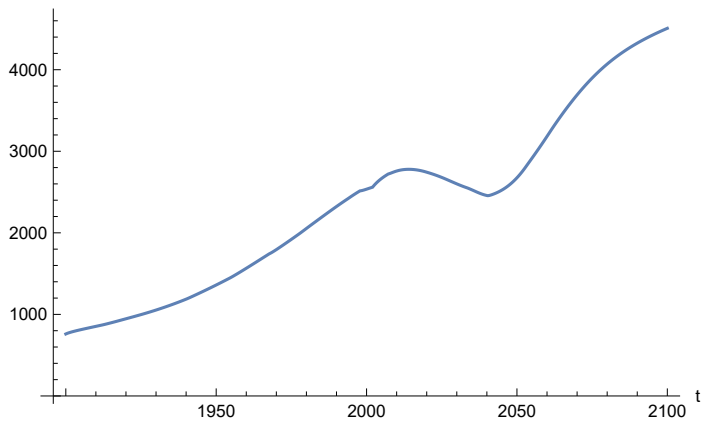
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.51279 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

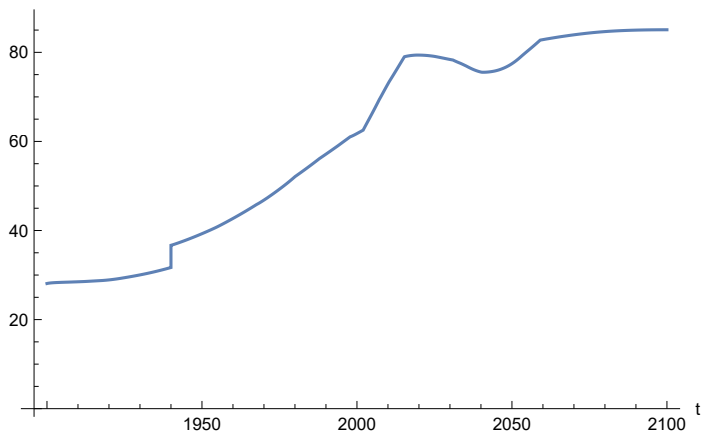
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

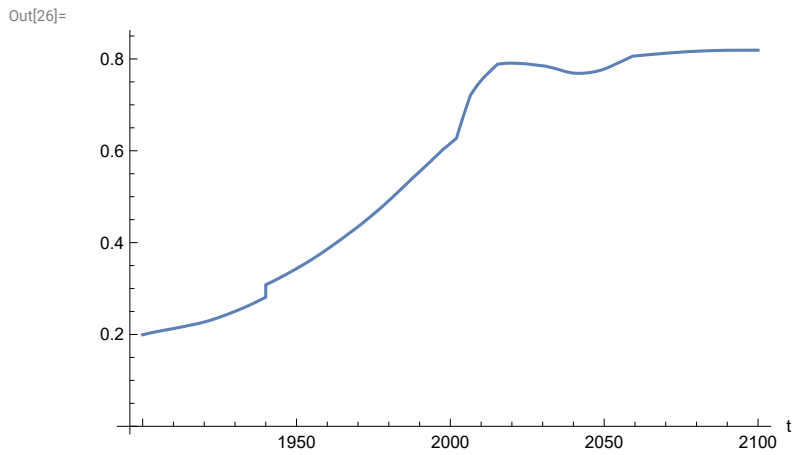
Out[24]=



In[25]:=

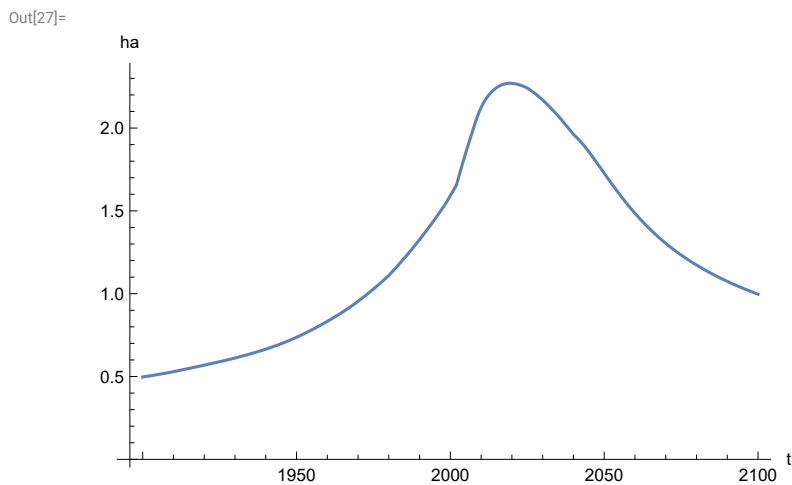
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,  
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

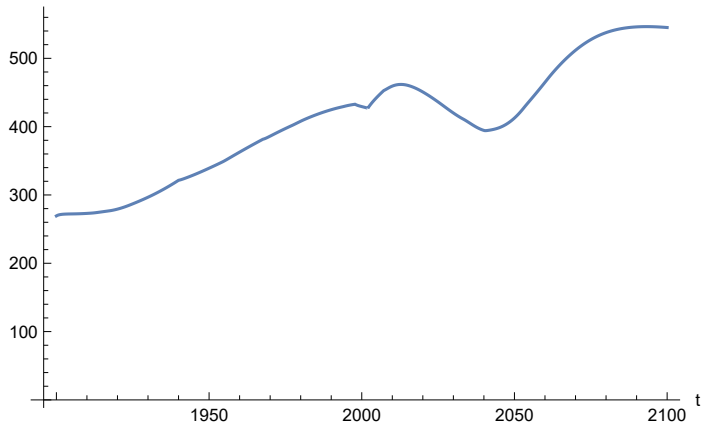
```
In[27]:= SystemModelPlot[basesim,  
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological  
_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

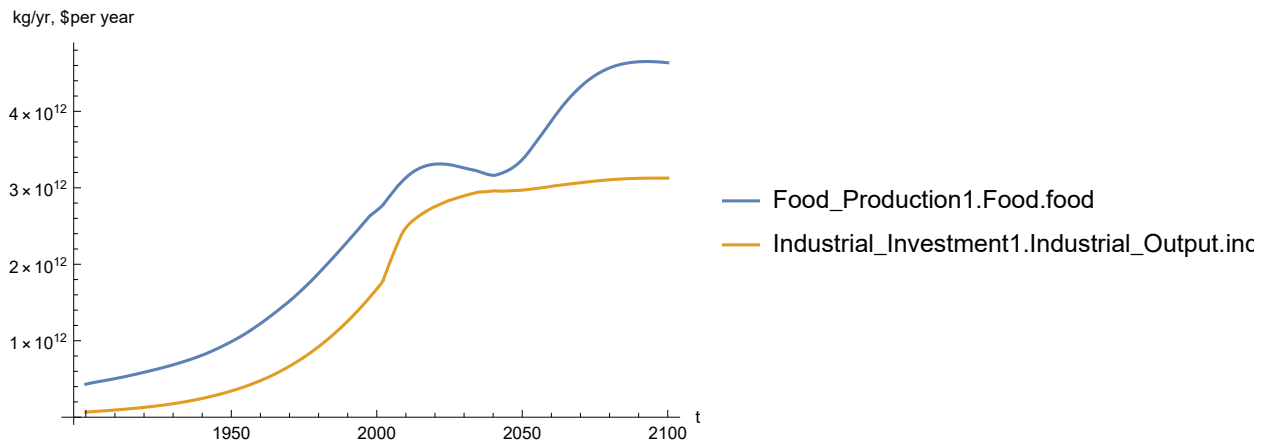
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

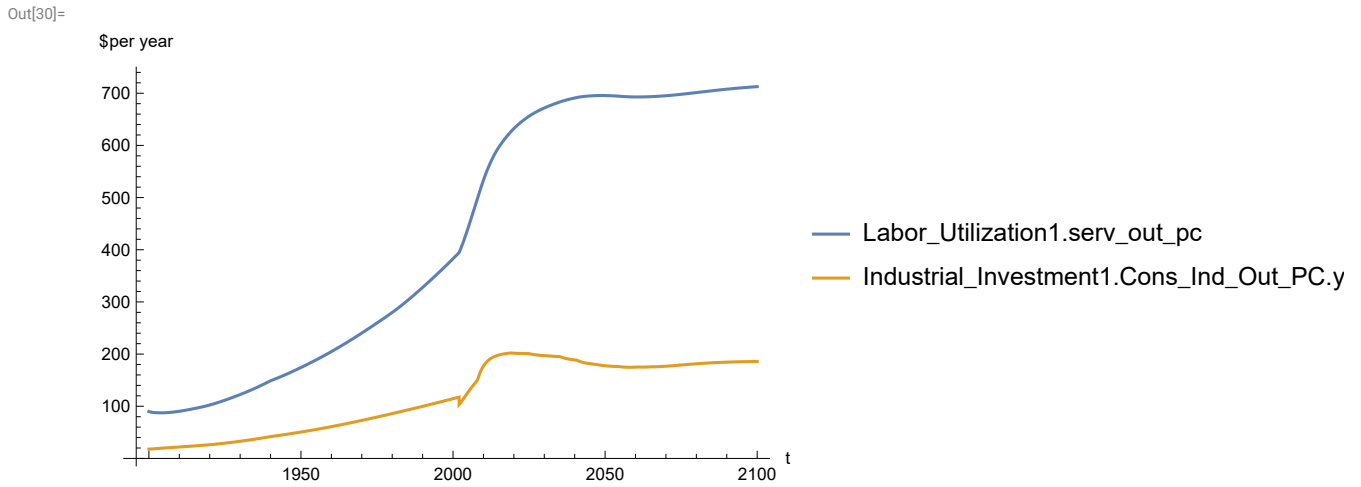
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

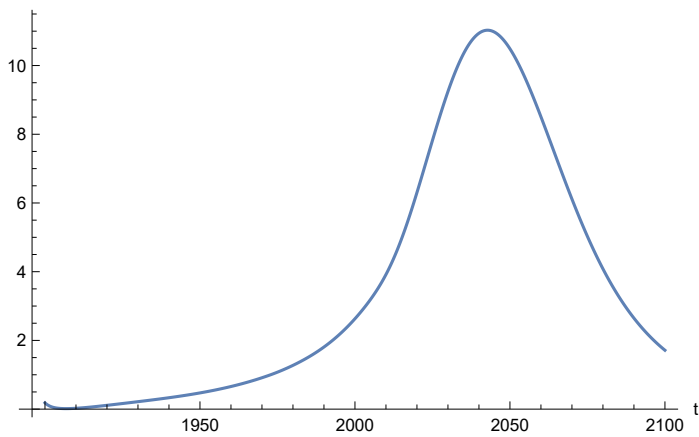


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 712.65
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[32]=
```



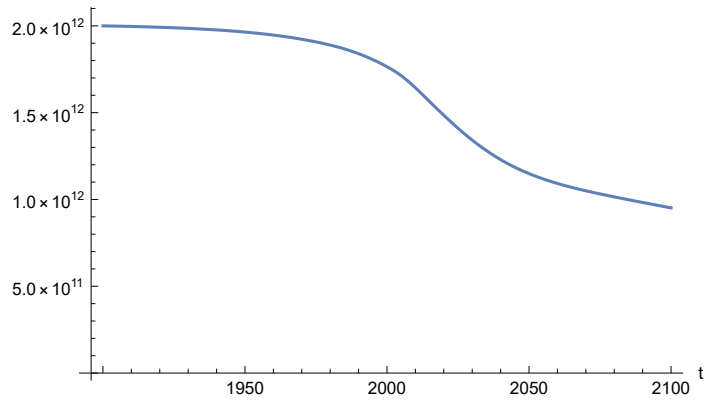
Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 11.028
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

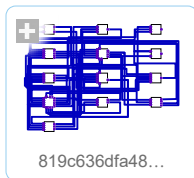


APPENDIX 9A2. LE/1.01, t_policy_year =2002. Baseline Scenario 8, Experiment 9A2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.01.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.99, 1.49, 1.88, 1.98, 1.98, 1.98, 1.98}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.99}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.49}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.88}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.98}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.98}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.98}
```

```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.98}
```

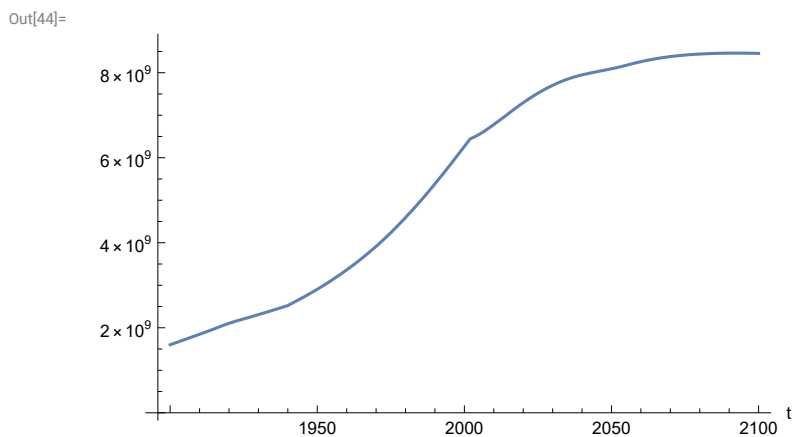
Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

```
Out[43]= SystemModelSimulationData [
   Model: W819c636dfa484280a11257195fda5710
  Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

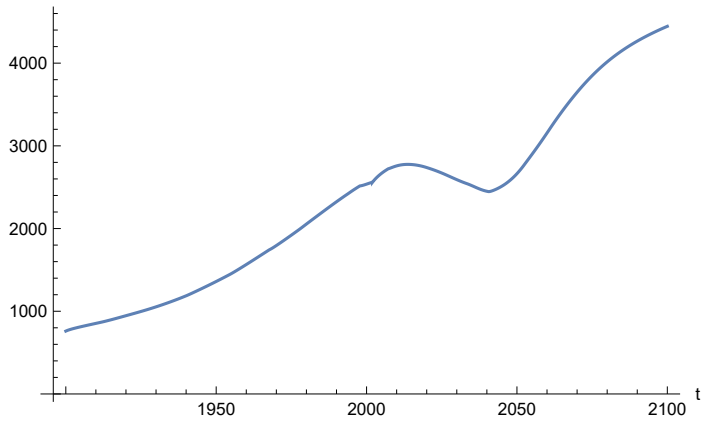
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.46137 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

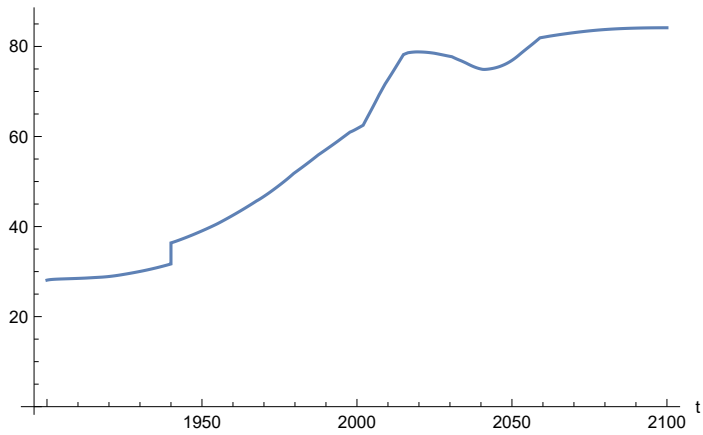
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

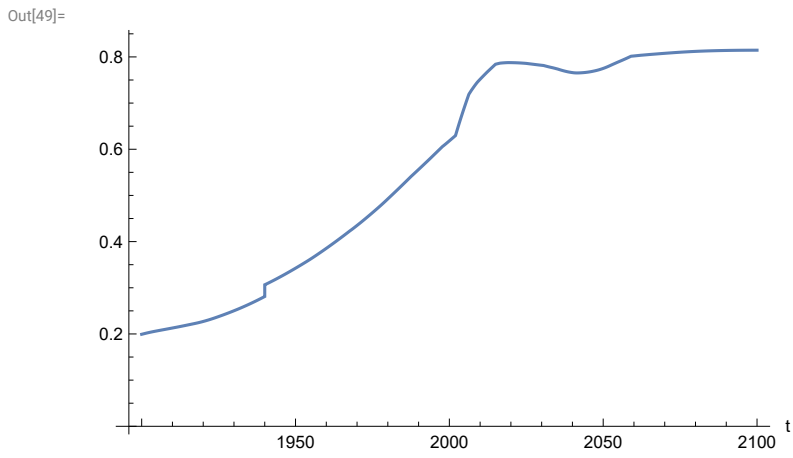
Out[47]=



In[48]:=

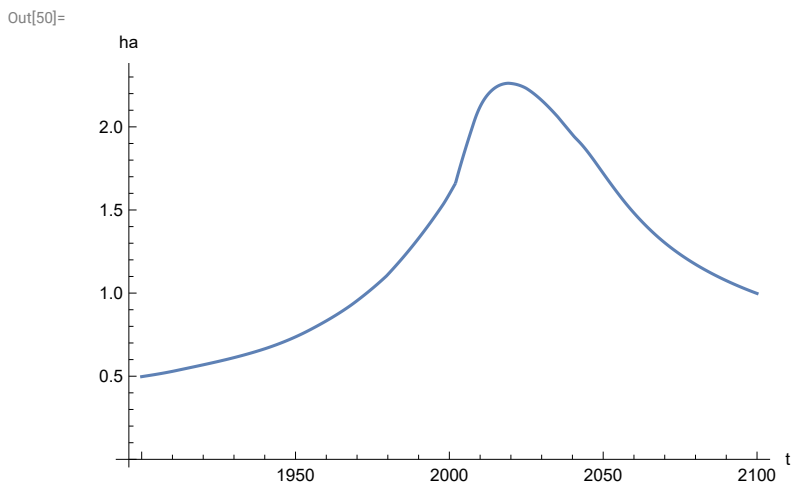
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
 {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

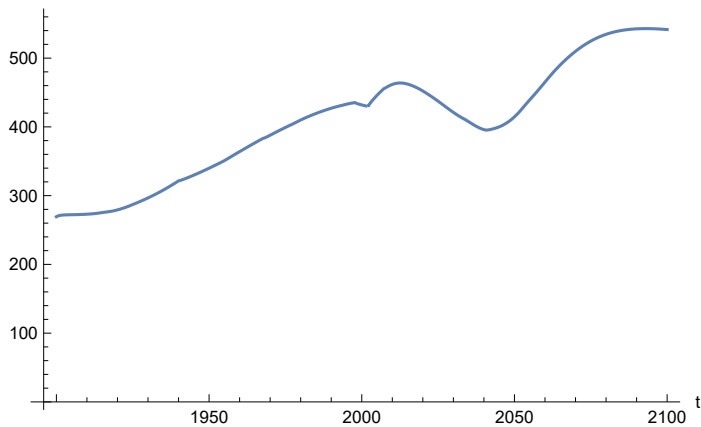
```
In[50]:= SystemModelPlot[basesim,
 {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

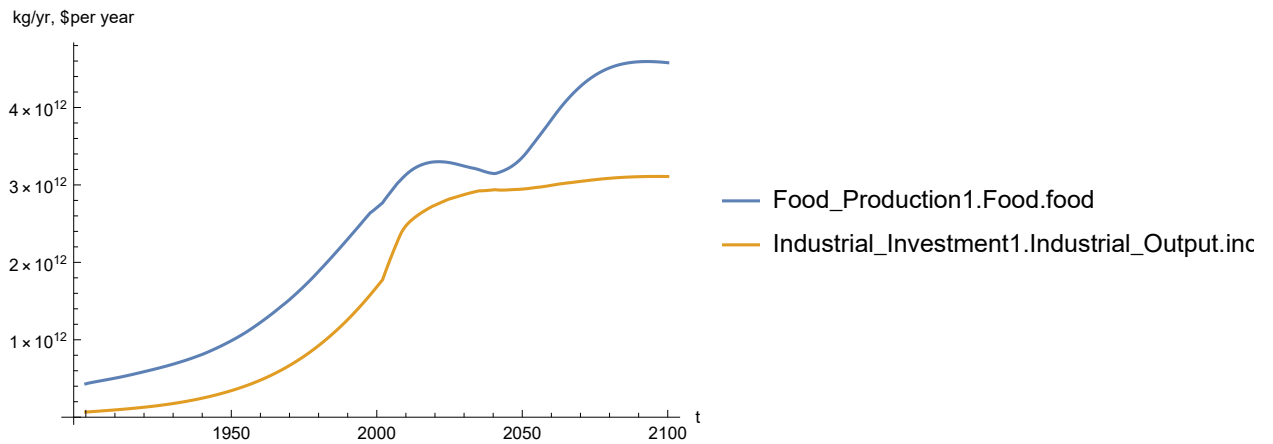
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

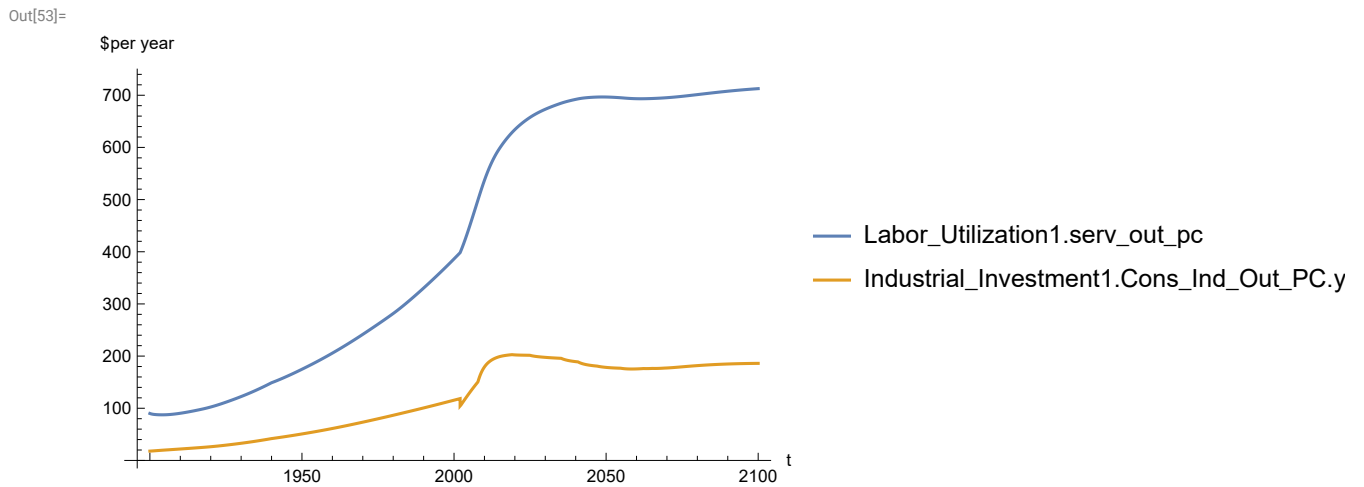
In[52]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

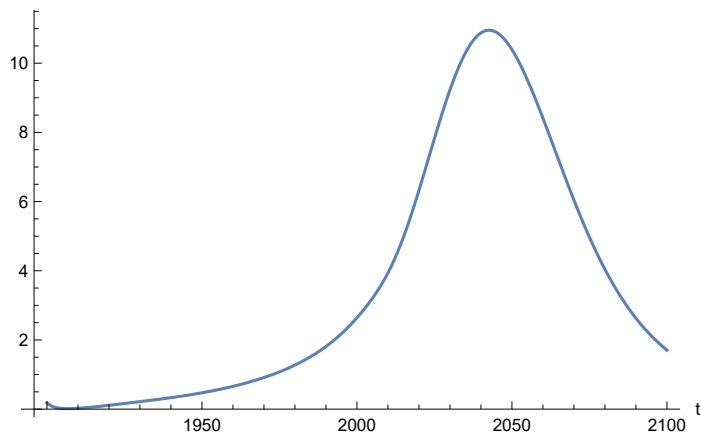


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 712.647
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



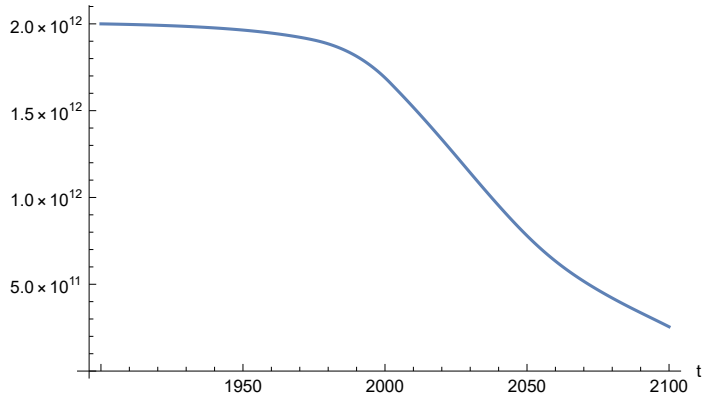
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.9537
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 9B1. BENCHMARK SCENARIO 8, Experiment 8B1. $LE = LE/1.03$, $t_policy_year = 2002$.

Last modified: 31 July 2022/13000 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

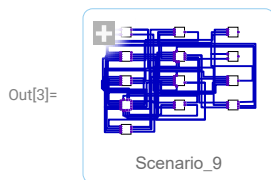
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

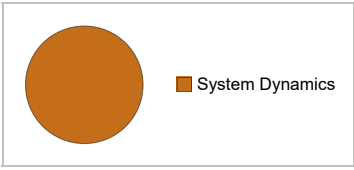
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario 9.

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_9"]
```



In[4]:= **mysummary = mysim["Summary"]**

	Model	SystemDynamics.WorldDynamics.World3.Scenario_9
	Description	Combining the measures of Scenarios #6 and #8
	Simulation Interval	True
	Plot	0
	Cells	106
	Background	True
Out[4]=	System	265
	System	265
	Diagram	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]**

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]**

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]**

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]**

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]**

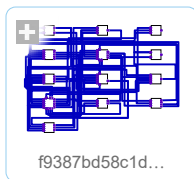
Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
Out[10]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
Out[11]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.03.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.97, 1.45, 1.84, 1.94, 1.94, 1.94}}|>]
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
Out[13]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.97}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
Out[14]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.45}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
Out[15]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.84}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
Out[16]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.94}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
Out[17]=
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.94}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```


```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.94}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.94}
```

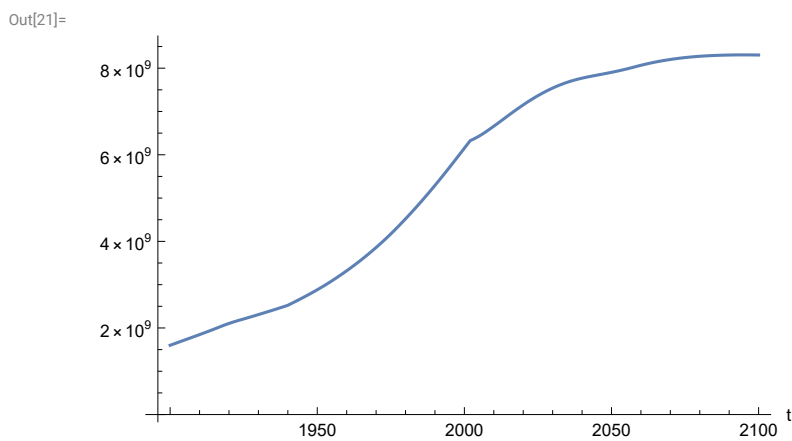
Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

```
Out[20]= SystemModelSimulationData [  Model: Wf9387bd58c1d4d60ac6580b4e39b5e46
  Time: 1.90 × 103 to 2.10 × 103 ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```



Find max and min of population values.

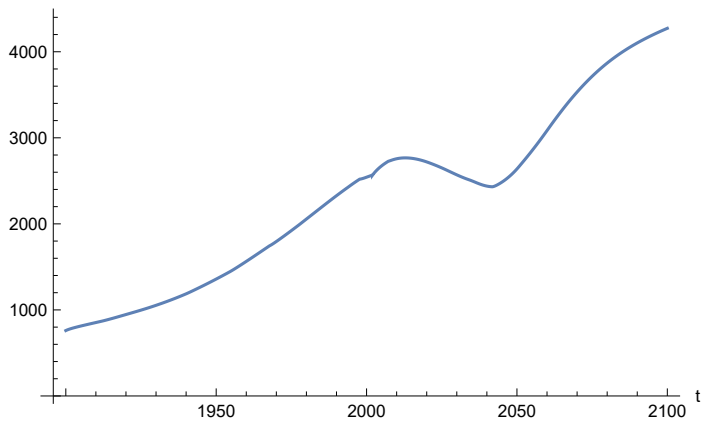
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is 8.30688 × 109
```

```
Minimum is 1.6 × 109
```

In[23]:= **SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]**

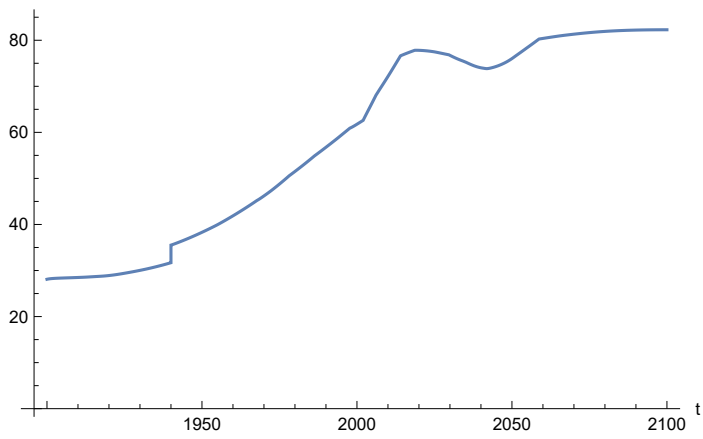
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]**

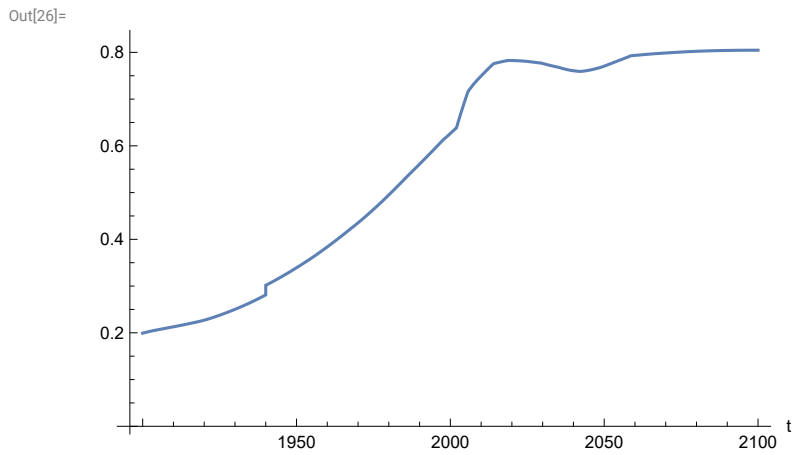
Out[24]=



In[25]:=

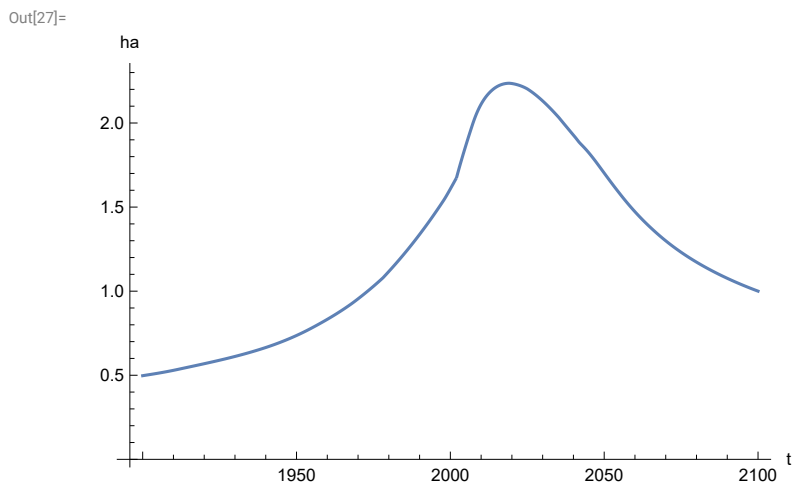
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

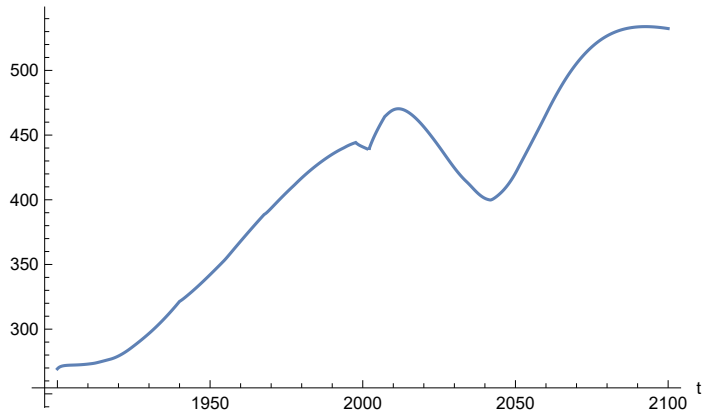
```
In[27]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

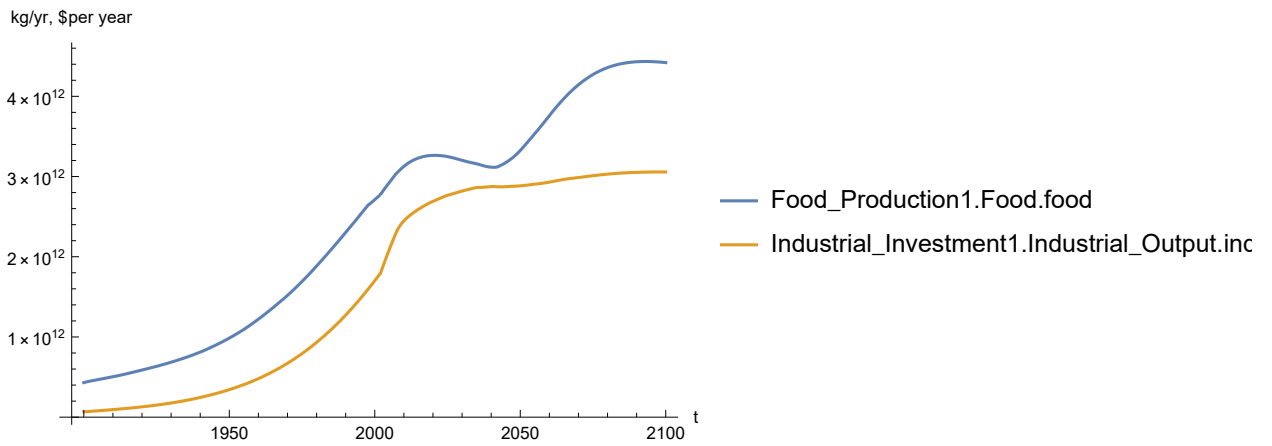
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

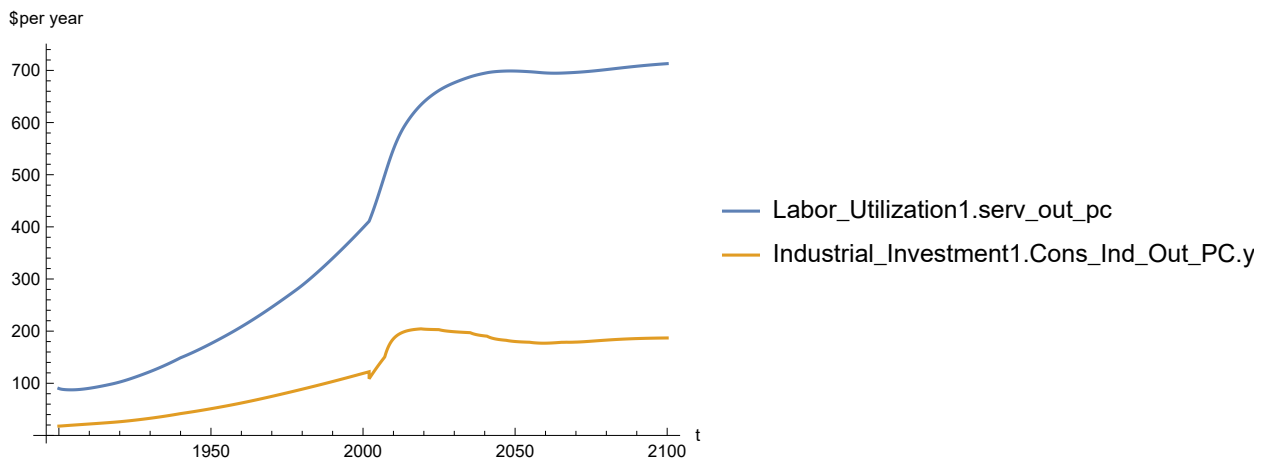
Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

Out[30]=



Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
```

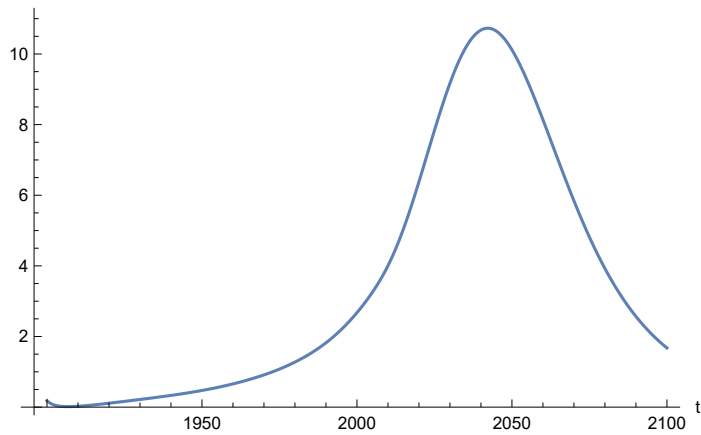
Maximum is 712.978

Minimum is 87.4451

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```

Out[32]=



Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
```

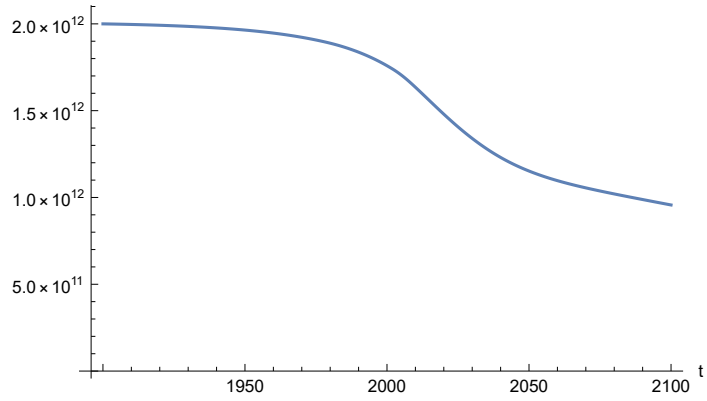
Maximum is 10.7299

Minimum is 0.0150765

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[34]=

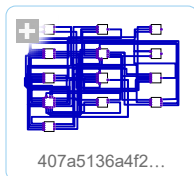


APPENDIX 9B2. LE/1.05, t_policy_year = 2002. Baseline Scenario 8, Experiment 9B2.

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.05.

```
In[35]:= strsim = SystemModel[
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.995, 1.42, 1.81, 1.90, 1.90, 1.90}}|>]
```

Out[35]=



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[36]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

Out[36]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.995}
```

```
In[37]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

Out[37]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.42}
```

```
In[38]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

Out[38]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.81}
```

```
In[39]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

Out[39]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.9}
```

```
In[40]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

Out[40]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.9}
```

```
In[41]:= SystemModel[strsim][
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

Out[41]=

```
{Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.9}
```


```
In[42]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[42]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.9}
```

Execute and plot various variables.

```
In[43]:= basesim = SystemModelSimulate[strsim]
```

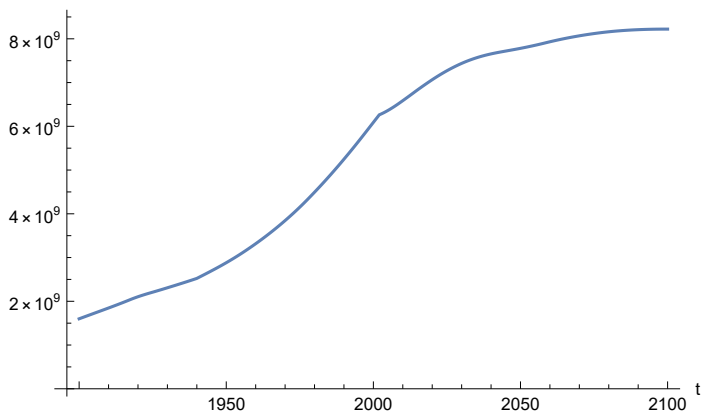
```
Out[43]=
```

```
SystemModelSimulationData [  Model: W407a5136a4f2467e9cb9028b8e4feccb  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[44]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[44]=
```



Find max and min of population values.

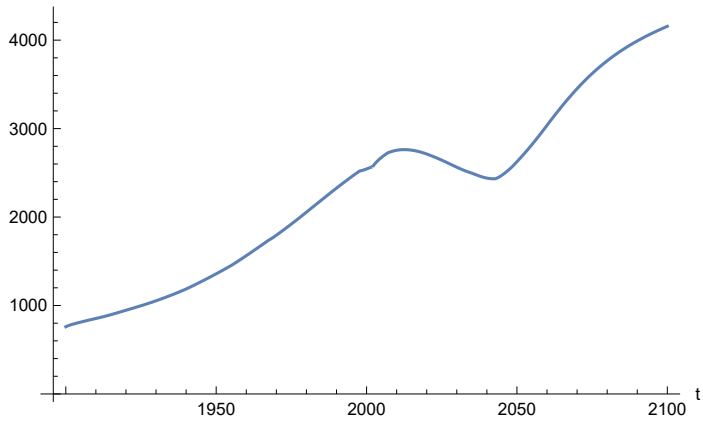
```
In[45]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $8.22181 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

```
In[46]:= SystemModelPlot[basesim, {"Food_Production1.Land_Yield.y"}]
```

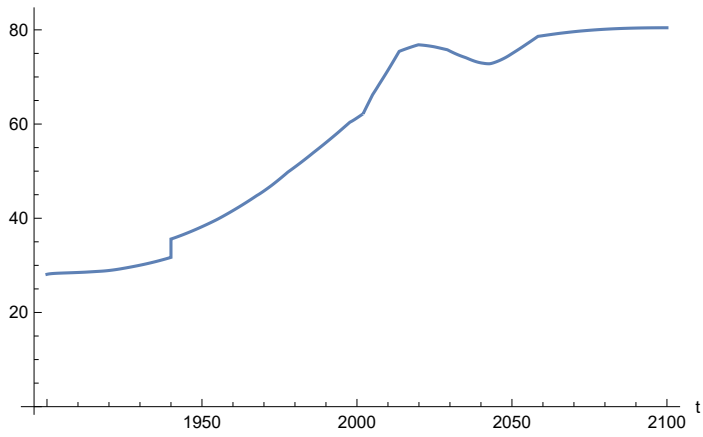
Out[46]=



Plot life expectancy, years.

```
In[47]:= SystemModelPlot[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]
```

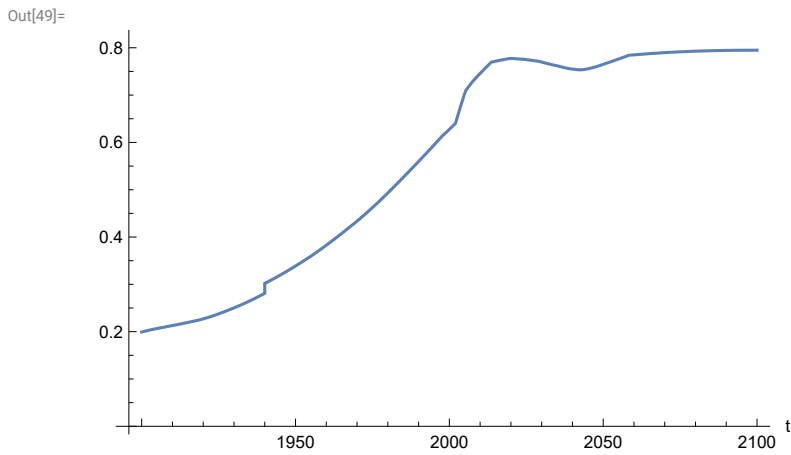
Out[47]=



In[48]:=

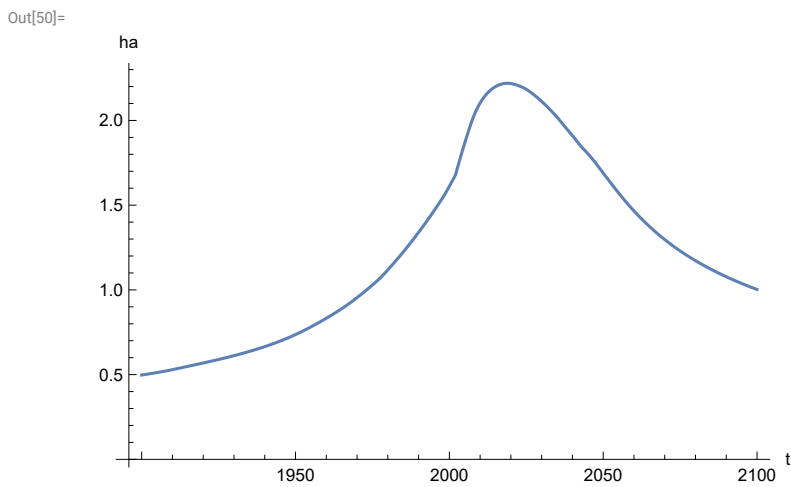
Plot human welfare index.

```
In[49]:= SystemModelPlot[basesim,
  {"Human_Welfare_Index1.HEF_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

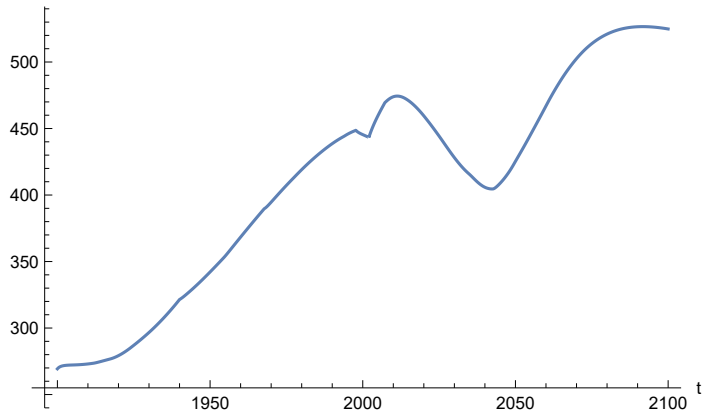
```
In[50]:= SystemModelPlot[basesim,
  {"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[51]:= **SystemModelPlot[basesim, {"Food_Production1.Food_PC.y"}]**

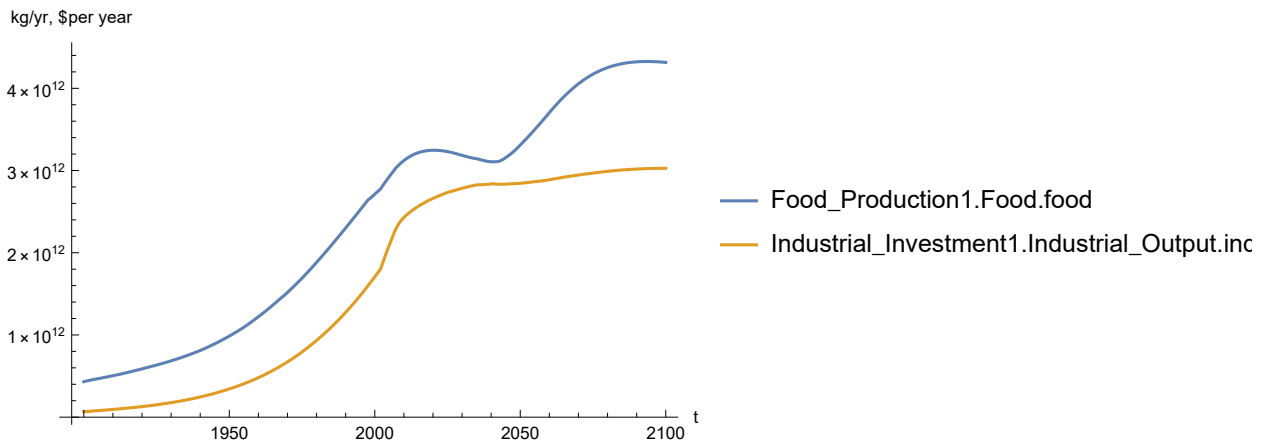
Out[51]=



Plot total food production (kg/year), and industrial output (dollars/year).

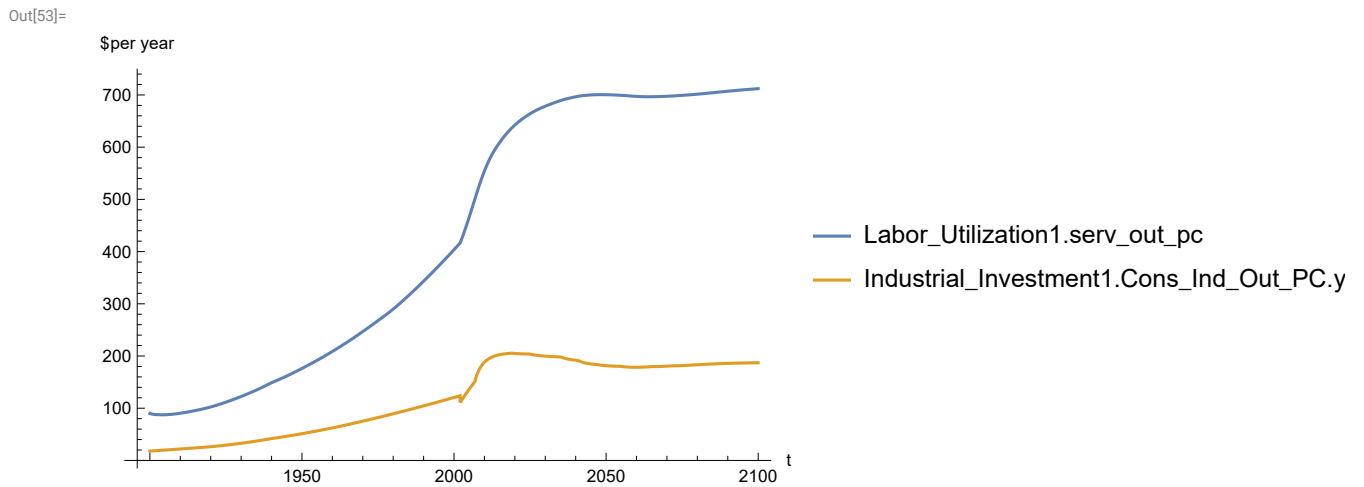
In[52]:= **SystemModelPlot[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]**

Out[52]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[53]:= SystemModelPlot[basesim,
 {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

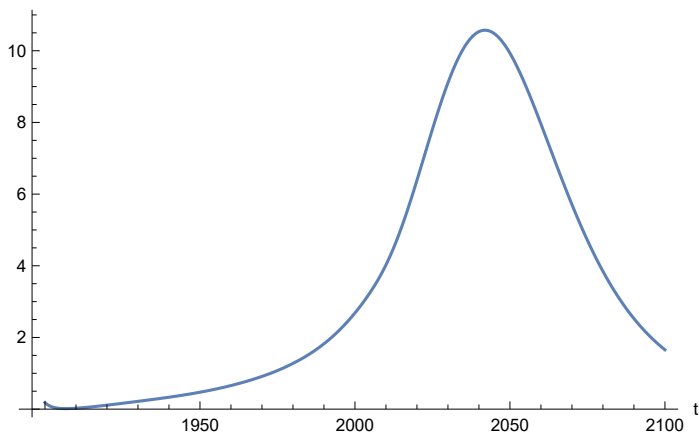


Find max and min of y values.

```
In[54]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 712.086
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[55]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
Out[55]=
```



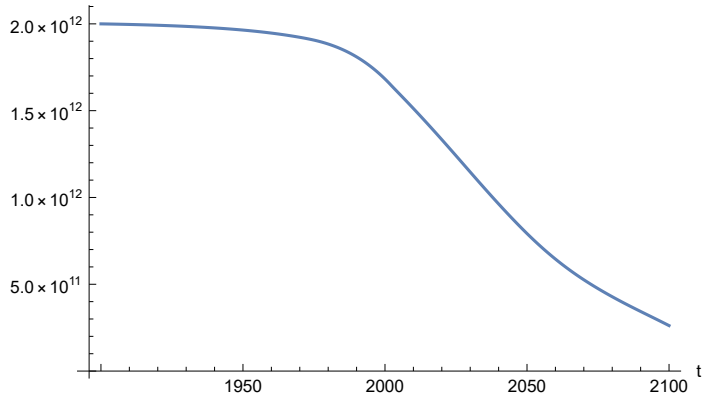
Find max and min of y values.

```
In[56]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.5733
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[57]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]
```

Out[57]=



APPENDIX 9C1. BENCHMARK SCENARIO 8, Experiment 9C1. $LE = LE/1.1$, $t_policy_year = 2002$.

Last modified: 30 July 2022/1312 US CT

Define a function that extracts range data from some scenario data. (The right-hand-side of this definition is specific to a *World3* data structure and assumes that the function whose range is being extracted is globally (i.e. ,not piecewise) defined.) The function does not check for errors.

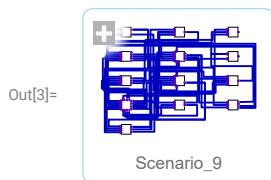
```
In[1]:= RangeData[data_] := data[[1]][[4]][[3]];
```

Define a procedure to determine and print minimum and maximum of “y” values. The procedure does not check for errors.

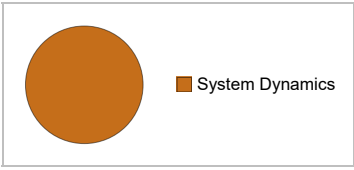
```
In[2]:= MinAndMax[data_] := (myscenseries = RangeData[data];  
Print["Maximum is ", Max[myscenseries]]; Print["Minimum is ", Min[myscenseries]])
```

Load Baseline Scenario .

```
In[3]:= mysim = SystemModel["SystemDynamics.WorldDynamics.World3.Scenario_9"]
```



In[4]:= **mysummary = mysim["Summary"]**

	M	SystemDynamics.WorldDynamics.World3.Scenario_9
	D	Combining the measures of Scenarios #6 and #8
	S	True
	P	0
	C	106
	B	True
Out[4]=	Sy	265
	Sy	265
	D	

Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals.

In[5]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1]"}]

Out[5]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[1] → 1}

In[6]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2]"}]

Out[6]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[2] → 1.1}

In[7]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3]"}]

Out[7]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[3] → 1.4}

In[8]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4]"}]

Out[8]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[4] → 1.6}

In[9]:= **SystemModel[mysim] [**
{"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5]"}]

Out[9]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[5] → 1.7}

```
In[10]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6]"}]
```

```
Out[10]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[6] → 1.8}
```

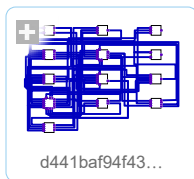
```
In[11]:= SystemModel[mysim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7]"}]
```

```
Out[11]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_1.y_vals[7] → 1.8}
```

Set Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals to LE/1.1.

```
In[12]:= strsim = SystemModel [
  mysim, <|"ParameterValues" → {"Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals" →
    {0.9, 1.36, 1.72, 1.82, 1.82, 1.82, 1.82}} |>]
```

```
Out[12]=
```



Show Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals.

```
In[13]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1]"}]
```

```
Out[13]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[1] → 0.9}
```

```
In[14]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2]"}]
```

```
Out[14]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[2] → 1.36}
```

```
In[15]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3]"}]
```

```
Out[15]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[3] → 1.72}
```

```
In[16]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4]"}]
```

```
Out[16]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[4] → 1.82}
```

```
In[17]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5]"}]
```

```
Out[17]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[5] → 1.82}
```

```
In[18]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6]"}]
```

```
Out[18]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[6] → 1.82}
```

```
In[19]:= SystemModel[strsim] [
  {"ParameterValues", "Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7]"}]
```

```
Out[19]= {Life_Expectancy1.Lifet_Mlt_Hlth_Serv_2.y_vals[7] → 1.82}
```

Set `t_policy_year` to 1970.

Execute and plot various variables.

```
In[20]:= basesim = SystemModelSimulate[strsim]
```

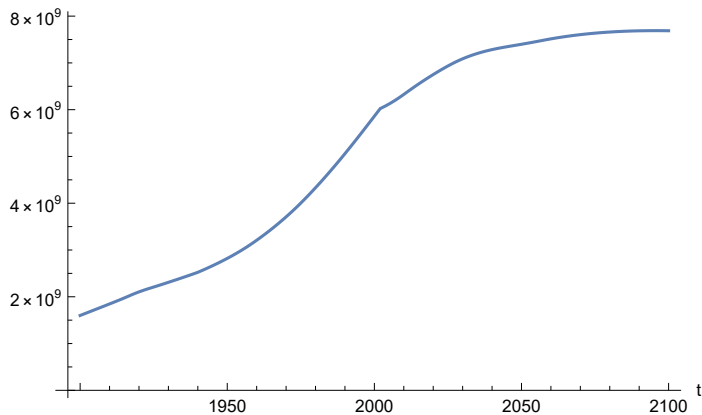
```
Out[20]=
```

```
SystemModelSimulationData [  Model: Wd441baf94f43476092571135c56f228b  
Time:  $1.90 \times 10^3$  to  $2.10 \times 10^3$  ]
```

Plot total population, people.

```
In[21]:= SystemModelPlot[basesim, {"Population_Dynamics1.Birth_Rate.pop"}]
```

```
Out[21]=
```



Find max and min of population values.

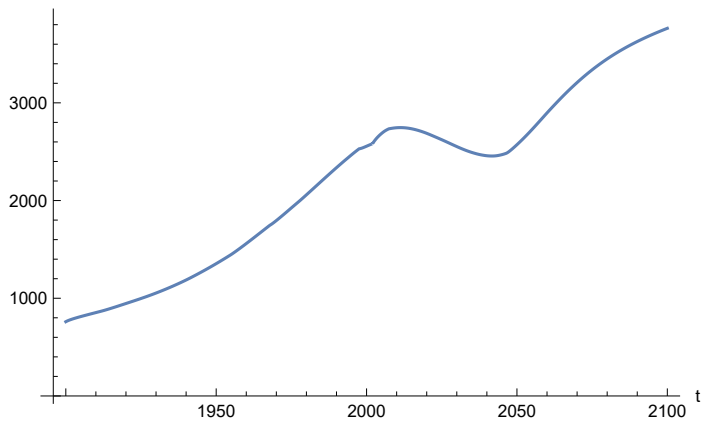
```
In[22]:= MinAndMax[basesim[{"Population_Dynamics1.Birth_Rate.pop"}]]
```

```
Maximum is  $7.68946 \times 10^9$ 
```

```
Minimum is  $1.6 \times 10^9$ 
```

In[23]:= **SystemModelPlot**[basesim, {"Food_Production1.Land_Yield.y"}]

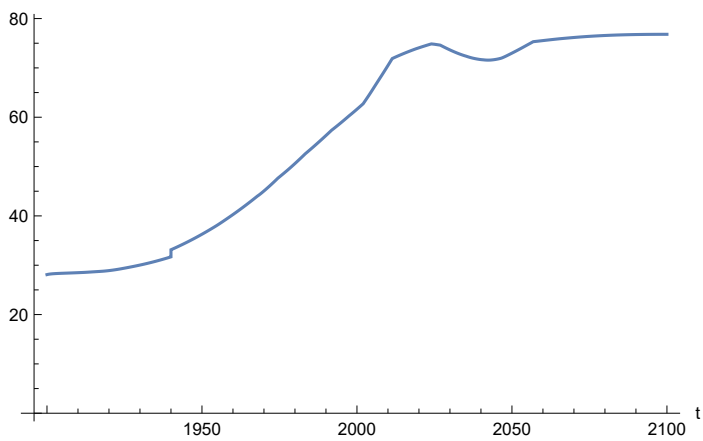
Out[23]=



Plot life expectancy, years.

In[24]:= **SystemModelPlot**[basesim, {"Life_Expectancy1.Life_Expectancy.y"}]

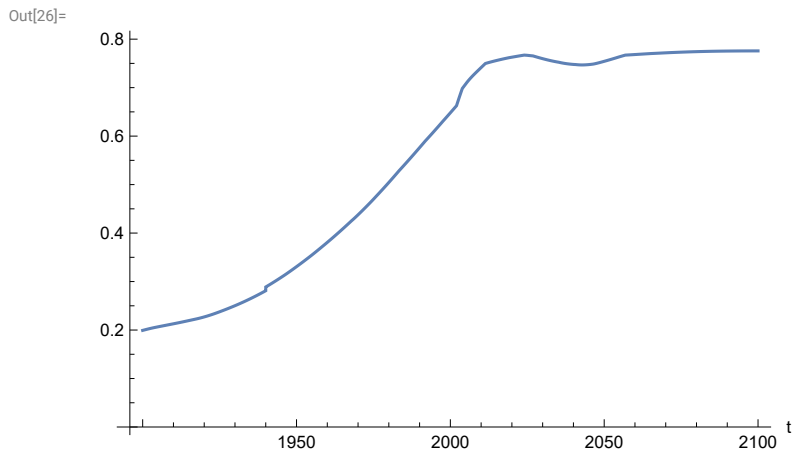
Out[24]=



In[25]=

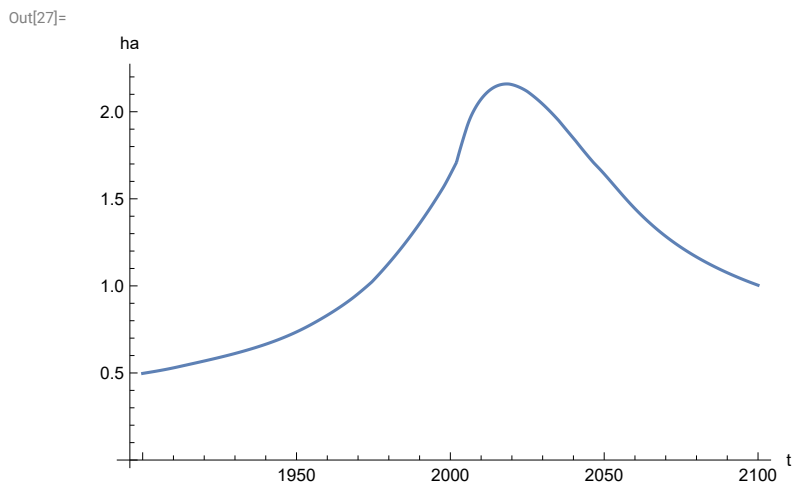
Plot human welfare index.

```
In[26]:= SystemModelPlot[basesim,
{"Human_Welfare_Index1.HWI_Human_Welfare_Index.hwi_human_welfare_index"}]
```



Plot per capita ecological footprint, hectares.

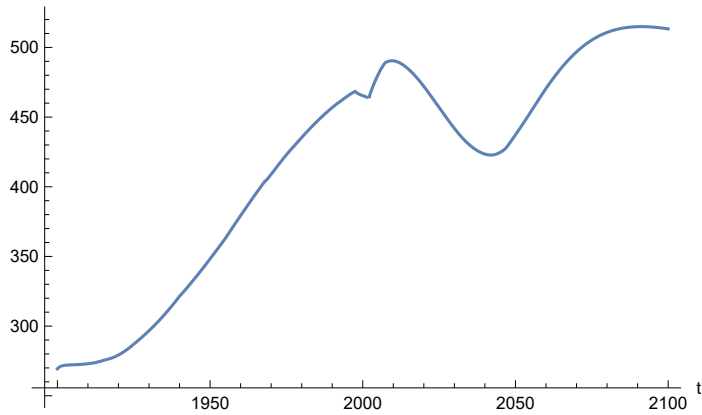
```
In[27]:= SystemModelPlot[basesim,
{"Human_Ecological_Footprint1.HEF_Human_Ecological_Footprint.hef_human_ecological_footprint"}]
```



Plot food production per capita (kg/year).

In[28]:= **SystemModelPlot**[basesim, {"Food_Production1.Food_PC.y"}]

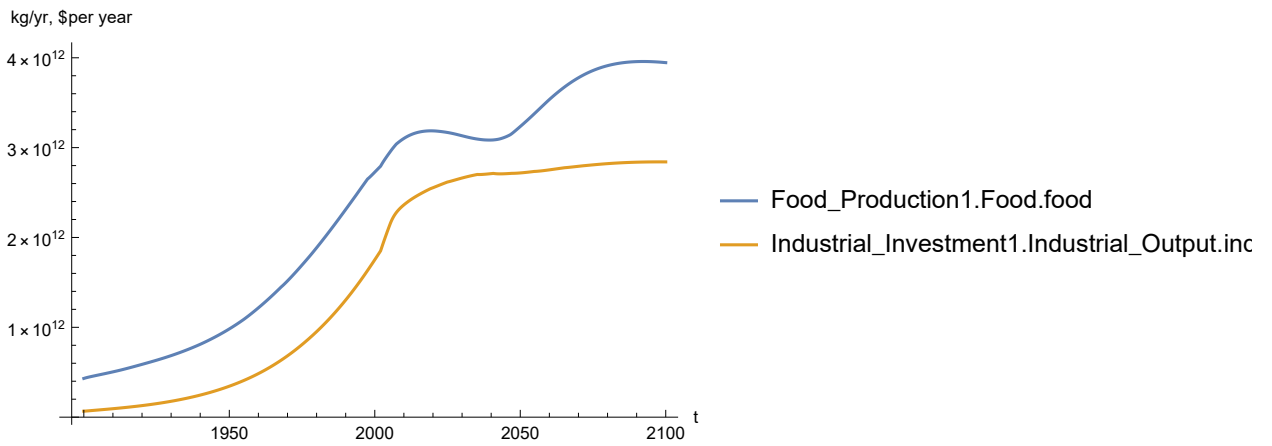
Out[28]=



Plot total food production (kg/year), and industrial output (dollars/year).

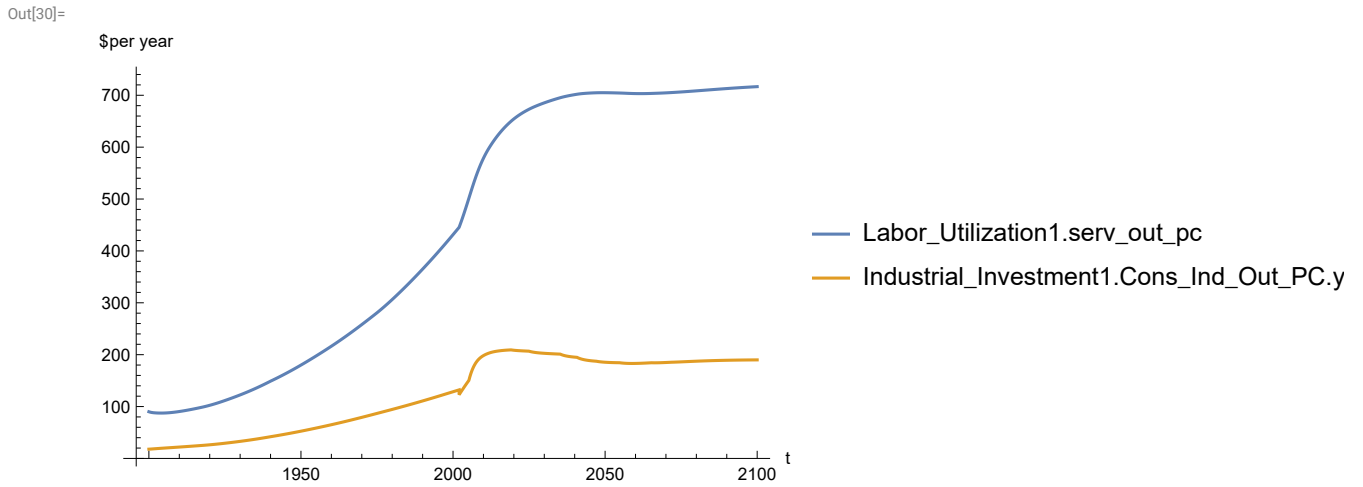
In[29]:= **SystemModelPlot**[basesim, {"Food_Production1.Food.food",
"Industrial_Investment1.Industrial_Output.industrial_output"}]

Out[29]=



Plot labor utilization per capita (dollars/year), and consolidated industrial output per capita (dollars/year)

```
In[30]:= SystemModelPlot[basesim,
  {"Labor_Utilization1.serv_out_pc", "Industrial_Investment1.Cons_Ind_Out_PC.y"}]
```

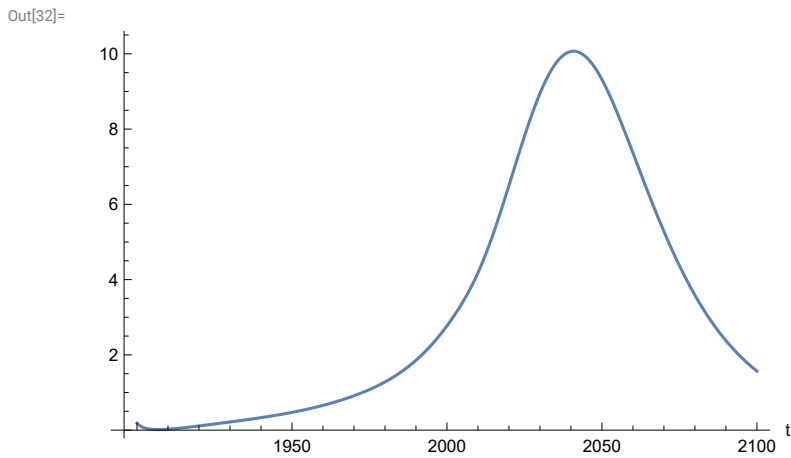


Find max and min of y values.

```
In[31]:= MinAndMax[basesim[{"Labor_Utilization1.serv_out_pc"}]]
Maximum is 716.627
Minimum is 87.4451
```

Plot persistent pollution index.

```
In[32]:= SystemModelPlot[basesim, {"Pollution_Dynamics1.PPoll_Index.y"}]
```



Find max and min of y values.

```
In[33]:= MinAndMax[basesim[{"Pollution_Dynamics1.PPoll_Index.y"}]]
Maximum is 10.0699
Minimum is 0.0150765
```

Plot non-renewable resources remaining.

```
In[34]:= SystemModelPlot[basesim, {"NR_Resource_Utilization1.NR_Resources.y"}]  
Out[ ]:=
```

